

**STATE OF CALIFORNIA  
AIR RESOURCES BOARD**

**MEETING OF THE  
RESEARCH SCREENING  
COMMITTEE**

**March 27, 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, 5<sup>th</sup> Floor  
Sacramento, California 95814  
(916) 445-0753**

**March 27, 2015  
9:00 a.m.**

**AGENDA**

- I. Approval of Minutes of Previous Meeting:
  - January 30, 2015 meeting iii-vi
  
- II. Discussion of New Research Projects:
  - 1) "Women's Cardiovascular Risk from Particulate Matter Exposure," University of California, Irvine, \$600,000, Proposal No. 2784-282 1
  - 2) "Are Adverse Health Effects from Air Pollution Exposure Passed on from Mother to Child?" University of, California, Davis, \$330,483, Proposal No. 2785-282 5
  - 3) "Greenhouse Gas Measurements at Walnut Grove Tower," University of California, Davis, \$200,000, Proposal No. 2786-282 9
  - 4) "Certification and In-Use Compliance Testing for Heavy-Duty Diesel Engines to Understand High In-Use NO<sub>x</sub> Emissions," University of California, Riverside, \$500,000, Proposal No. 2787-282 15
  - 5) "Investigative Modeling of PM<sub>2.5</sub> Episodes in the San Joaquin Valley Air Basin in Recent Years," University of California, Davis, \$199,928, Proposal No. 2788-282 21
  
- III. Discussion of Draft Final Reports:
  - 1) "Technical Analysis of Vehicle Load Reduction Potential for Advanced Clean Cars," Control-Tec, \$162,120, Contract No. 13-313 25
  - 2) "Evaluating the Benefits of Light Rail Transit," University of California, Irvine, \$200,00, Contract No. 12-313 29



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Cal/EPA Headquarters Building  
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(916) 445-0753**

**January 30, 2015  
9:00 a.m.**

**MINUTES**

**RSC Members in Attendance via teleconference**

Harold Cota  
Forman Williams  
Steven Japar  
Philip Fine  
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 October 3, 2014 meeting were approved.

**I. Proposed Contract Augmentation**

- 1) "Modeling Household Vehicle & Transportation Choice & Usage," University of California, Davis, \$45,000, Contract No. 11-322

One Committee member asked for clarification that the project was progressing adequately on tasks that were not affected by delays in the Air Resources Board (ARB) delivery of Department of Motor Vehicles data, and for assurance that there are qualified graduate student researchers available to continue work on the project. Staff provided reassurance that the project was progressing adequately and that two qualified students are available to continue the work.

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

The Committee approved the augmentation.

## II. Draft Final Reports

- 1) "Health Effects of Central Valley Particulate Matter," University of California, Davis, \$496,429, Contract No. 09-330

One Committee member commented that the report is rather unevenly written, a suggestion that the submitted manuscript (currently Chapter 4) be moved to an appendix and the material be summarized into a new Chapter 4, that the discussion about some of the counter-intuitive results be expanded, that a rationale for the selected mouse strain be added, and that the relatively high responses of control animals be discussed. The member expressed disappointment that some of the counter-intuitive findings had not been experimentally followed up on. Staff agreed that the study yielded several avenues that warranted further investigation, but also indicated that they were outside the scope and resources available for this study. Another member agreed that the submitted manuscript should be moved to an appendix and that a summary of the manuscript be inserted in its place. The member also asked for more in-depth discussion of counter-intuitive results from Figure 1, and asked that the investigators discuss what the effect of treating particulate matter (PM) with harsh solvents during the extraction process has on the bioavailability of the PM components.

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) "Risk of Pediatric Asthma Morbidity from Multi-Pollutant Exposures," University of California, Irvine, \$285,000, Contract No. 10-319

Staff informed the Committee that the draft report was sent to the Office of Environmental Health Hazard Assessment for an outside review. Their comments for minor clarifications have been sent to the investigator, who will address the comments in the report. The Committee noted that the report was well written overall and clearly presented the approach and results of the study. A Committee member commented that the report included a substantial number of results and models, and the volume of the epidemiological results in the report makes it difficult to discern the significant associations. The Committee requested that the significant health associations presented in the tables be highlighted to make it easier for the reader to follow. Staff responded that these concerns will be conveyed to the investigator.

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) "Reducing Air Pollution Exposure in Passenger Vehicles and School Buses," University of California, Los Angeles, \$150,000, Contract No. 11-310

One Committee member commented that the study was straightforward for determining the effectiveness of high efficiency filtration using simple measurements, and that the results were promising and warranted follow-up study. The Committee member also stated that traffic exposure to ultrafine particles is high and is of concern. The Committee member also requested that preliminary information on the cost of the filtration technology be included in the final report.

A second Committee member also agreed with the first member's comments and that the study was well done and clearly to the point. A Committee member stated that in particular, it would be helpful to include a discussion section in the final report that summarizes the practical issues and usefulness of the study's findings. The member also stated that the data analysis was straightforward, with excellent empirical work, but would be strengthened by performing additional statistical analysis, such as a t-test, on the data to show the statistical significance of the results.

Staff stated that they will work with the principal investigator to obtain a revised final report that includes requests and suggestions of the Committee.

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

The Committee approved the report. Yifang Zhu recused herself from this item.

- 4) "Development of a Portable In-Use Reference Particulate Matter Measurement System," University of California, Riverside, \$300,000, Contract No. 10-311

Staff updated the Committee with the information about the new Figure 17 and asked if anyone had any comments on what additional testing should be included. A Committee member stated that organic PM/sulfate PM have a history of sampling issues. Any high load testing in the long term would be able to identify and eliminate the problem. Staff stated that (i) future testing on chassis dyno can be done; (ii) any sampling in the future would be done using the stainless steel tubing which should eliminate the artifacts and; and (iii) ARB staff will analyze filters from Version 2.0a and 2.0b to identify that the problem is in fact related to sulfate.

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

The Committee approved the report.

- 5) "Determination of the Spatial Distribution of Ozone Precursor and Greenhouse Gas Concentrations and Emissions in the Los Angeles Basin," University of California, Los Angeles, \$299,968, Contract No. 09-318

The Committee was very impressed with the scientific depth and detail of writing in the final report. They commented that the project developed a very rich data set and that much more data analysis is left to do, especially in exploring the spatial distributions of species.

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

The Committee approved the report.

- 6) "Assessment of the Emissions and Energy Impacts of Biomass and Biogas Use in California," University of California, Irvine, \$167,497, Contract No. 11-307

One Committee member noted the report's conclusion that compressed natural gas production for vehicles appears to be the best option of biomass use, and questioned the uncertainty of that conclusion. The same Committee member also questioned Table 5's statement that 'low char and tar content' would result from gasifier operation, and suggested that this should be 'more char and less tar content'.

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

The Committee approved the report.

The meeting adjourned at 9:45 a.m.

**DISCUSSION OF A NEW RESEARCH PROJECT**

**ITEM NO.:** II.1

**DATE:** March 27, 2015

**PROPOSAL NO.:** 2784-282

**STAFF EVALUATION OF A NEW RESEARCH PROPOSAL**

**TITLE:** Women's Cardiovascular Risk from Particulate Matter Exposure

**CONTRACTOR:** University of California, Irvine

**PRINCIPAL INVESTIGATOR:** Michael Kleinman, Ph.D.

**CONTRACT TYPE:** Interagency Agreement

**TOTAL AMOUNT:** \$600,000

**CONTRACT TERM:** 36 months

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

**I. SUMMARY**

Epidemiological studies suggest that women have a greater relative risk of cardiovascular mortality than men. Yet animal studies designed to shed light on the mechanism of toxicity of particulate matter (PM) are mostly conducted on male animals. This study will compare the response to particulate matter of female and male rodents and investigate possible mechanism of PM2.5 toxicity unique to females. Evidence from the scientific literature shows that: 1) PM2.5 exacerbates cardiovascular disease severity and progression; and 2) impaired ovarian function is associated with cardiovascular disease. Studies that focus on women's health have found an increased risk of mortality from exposure to air pollution compared to studies with both men and women. These studies include the California Teachers Cohort Study, Women's Health Initiative, Nurses' Health Study, and the Adventist Health Air Pollution Study. Statistically, heart attacks are more deadly and disabling for women than for men; 38 percent of women die within one year of their first heart attack, compared with 25 percent of men. This research project will investigate whether the increased cardiovascular effects of PM2.5 exposure can be observed in a rodent model and the possible role of the ovarian system for these effects. Animals exposed to concentrated

PM2.5 will be evaluated for evidence of cardiovascular disease such as markers of oxidative stress, decreased heart rate variability, and atherosclerotic plaque development. This project is among the first to address how different hormonal conditions can influence the levels of various toxicological endpoints in animals subjected to the same exposure conditions to PM and would identify additional risk factors which may need to be taken into account when evaluating exposure to PM. The results are expected to help us understand why epidemiological studies have found a greater risk of cardiovascular mortality for women than men, which would suggest that women's cardiovascular health be included as an important risk factor in the next national air quality standard review.

## **II. TECHNICAL SUMMARY**

### **Objective**

This study will investigate the mechanisms of PM2.5 cardiovascular toxicity occurring in females using a rodent model. The hypothesis that will be tested in this proposal is that the cardiovascular effects of PM exposure observed in women are due changes in the estrogen production secreted by the ovaries. The experiments will be conducted in a rodent model that has been established in previous studies as suitable for investigating PM mediated cardiovascular diseases. A subset of the female rodents will be chosen to investigate possible changes in physiology due to aging, such as loss of ovarian function which may affect PM2.5 mediated effects.

### **Background**

Several epidemiological studies have found a greater risk for mortality from exposure to PM for older women when compared to men. These studies include the California Teachers Cohort Study, Women's Health Initiative, Nurses' Health Study, and the Adventist Health Air Pollution Study. Statistically, heart attacks are more deadly and disabling for women than for men; 38 percent of women die within one year of their first heart attack, compared with 25 percent of men. These and other published studies suggest that women have a greater relative risk of PM-mediated cardiovascular mortality than men. However, animal studies designed to shed light on the mechanism of toxicity for PM are mostly conducted on male animals, which may have inherently different sensitivities to PM compared to female animals. This discrepancy has not gone

unnoticed in the scientific community and as of October 2014, NIH applications are required to “address the influence of sex in the design and analysis of biomedical research with animals and cells.” Results from this study will be one of the first to help researchers answer this question and more importantly may provide insight into the higher relative risks of PM mediated cardiovascular mortality in women. In addition, this study may elucidate which possible physiological factors may make females more sensitive to PM mediated cardiovascular toxicity.

### **Proposal Summary**

The researcher will prepare a literature review summarizing work performed regarding gender differences in cardiovascular outcomes in both epidemiological studies and animal toxicological studies. In addition, any information that may address a physiological basis for a gender difference for PM toxicity will be summarized. The experiments will be conducted in a rodent model which has been established in previous studies as suitable for investigating PM mediated cardiovascular disease. In addition, a subset of the female rodents will be chosen to investigate possible changes in physiology due to aging, such as loss of ovarian function which may affect PM mediated effects.

The experiments consist of groups of male, female and ovariectomized female mice who are deficient for the Apolipoprotein E (ApoE) protein, which increases their susceptibility for atherosclerosis. The group of ovariectomized female mice will be further subdivided between those who receive replacement hormone therapy and those who do not. All test groups and appropriate control groups will be exposed to concentrated PM<sub>2.5</sub> or filtered air for four months. Animals will be then be sacrificed and evaluated for evidence of cardiovascular disease by measuring heart rate variability, atherosclerotic plaque development, and changes in ovarian function.

Also, oxidative/nitrosative stress- and apoptosis-related endpoints will be measured in the plasma, ovary, myocardium, and aorta. Plasma endpoints include measured plasma estradiol and progesterone concentrations. Stereological methods will be used to enumerate ovarian follicles and quantify fibrotic cardiovascular function-related endpoint and hypertrophic changes in the left ventricle. Myocardium and aortic endpoints include the measurement of blood pressure and electrocardiography.

The results will be analyzed to determine whether the female mice are susceptible more to the cardiovascular effects of PM2.5 than male mice. In addition, analysis will be conducted to determine if ovariectomized mice are more susceptible than mice with intact ovaries and whether hormone replacement is protective.

### **III. STAFF COMMENTS**

The proposal was reviewed by Research Division (RD) staff. Changes requested during this initial review included use of the ApoE deficient mouse strain, emphasis on PM2.5 exposures, and the inclusion of male mice as a control group. Additional review by RD staff and from the Office of Environmental Health Hazard Assessment is ongoing. Concerns regarding the project which may arise during this secondary review will be forwarded to the principal investigator and discussed at the Research Screening Committee meeting.

The principal investigator, Michael Kleinman, is proposing a systematic and comprehensive approach for selection of test groups as well as exposure protocols. The study is well designed and the investigator has extensive experience in the field given his publications regarding the physiological effects of concentrated ambient PM exposure in rodents and ongoing work with PM rodent exposure. In addition, he is partnering with co-investigators who have experience in performing toxicological assays and physiological techniques in mouse gender comparison studies.

The completion of this study will greatly enhance the knowledge base for future gender based toxicological investigations and elucidate the possible physiological mechanisms regarding gender differences in the risk of cardiovascular mortality.

### **IV. STAFF RECOMMENDATION**

Staff recommends the Research Screening Committee approve this proposal for a total amount not to exceed \$600,000 subject to inclusion of any changes and additions specified by the Committee.

## DISCUSSION OF A NEW RESEARCH PROJECT

ITEM NO.: II.2

DATE: March 27, 2015

PROPOSAL NO.: 2785-282

### STAFF EVALUATION OF A NEW RESEARCH PROPOSAL

**TITLE:** Are Adverse Health Effects from Air Pollution Exposure Passed on from Mother to Child?

**CONTRACTOR:** University of California, Davis

**PRINCIPAL INVESTIGATOR:** Lisa A. Miller, Ph.D.

**CONTRACT TYPE:** Interagency Agreement

**TOTAL AMOUNT:** \$330,483

**CONTRACT TERM:** 24 months

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

#### I. SUMMARY

In animal models, there is some experimental evidence that early life environmental exposures can persistently alter developmental programming through mechanisms that alter gene function such that adverse health effects can be manifested in two or more generations without additional exposure (epigenetic changes). A previous project funded by the Air Resources Board (ARB) studied of nonhuman primates exposed during infancy to high levels of particulate matter less than 2.5 microns in diameter (PM2.5) enriched with wildfire smoke from a series of wildfires during summer of 2008. When evaluated at three years of age, the 2008 animals had adverse changes in lung function and cytokine markers of immune function compared to animals of the same age that were born in 2009 and not exposed to elevated levels of air pollution. This suggests that epigenetic changes could have taken place in the 2008 animals. This project will extend the original investigation by evaluating immune and lung function parameters in the 2008 female animals and their offspring. The investigator hypothesizes that the immune and lung function profile changes imposed by the high PM2.5 plus wildfire smoke exposure during infancy can be transmitted into subsequent generations (epigenetic effect), and that the epigenetic effects may be detected in the

form of histone modification profiles in both the mother and her offspring. The project has three specific aims: 1) determine if the peripheral blood immune function response previously observed in the 2008 animals remains modulated and whether the same response is evident in the animals' unexposed offspring; 2) determine if changes in parameters of lung health (volume, density, obstruction) that were observed in the 2008 animals remain compromised and whether the same response is evident in the animals' unexposed offspring; and 3) determine if the high PM2.5 plus wildfire smoke exposure elicited peripheral blood epigenetic changes in the form of histone modifications in the 2008 animals and whether the same changes are evident in the animals' unexposed offspring.

## **II. TECHNICAL SUMMARY**

### **Objective**

The project will determine whether: 1) the modulated peripheral blood immune function response previously observed in the 2008 animals remains, and whether the same response is evident in the animals' unexposed offspring; 2) parameters of lung health (volume, density, obstruction) that were compromised in the 2008 animals continue to be compromised and whether the same response is evident in the animals' unexposed offspring; and 3) peripheral blood epigenetic changes in the form of histone modifications are evident in the 2008 animals and their unexposed offspring.

### **Background**

There is suggestive evidence from epidemiologic and animal studies that air pollution exposure during early life could lead to persistent changes in physiological function that impact health later in life. While environmental exposures do not alter an individual's genetic code, recent evidence suggests that environmental exposures can induce changes in how genes function. These changes in gene function can be passed on to offspring, who then have the same change in responses as their parent, without having experienced the exposures. A previously funded ARB study of nonhuman primates exposed to high PM2.5 enriched with wildfire smoke during infancy found persistent changes in lung function and reduced production of markers of immune response to microbial challenge compared to animals of the same age which had not been exposed. The finding of a persistent change in both lung and immune function long after exposure returned to typical levels suggests that epigenetic changes occurred in the study

animals that led to a less robust response to microbial challenge. These results have public health significance, in that animals, and by extension humans, who have reduced responses to microbial challenge are at increased risk of contracting infectious diseases. If this risk can be transmitted to offspring who have not undergone the exposure that induced the epigenetic change, the implication is that disease burden can be maintained long after exposures have significantly declined in exposed individuals and extend to unexposed individuals.

### **Proposal Summary**

The California National Primate Center at the University of California, Davis houses over 5000 primates, primarily rhesus macaques. The previous study included 100 rhesus macaques born in each of 2008 and 2009, half male and half female. This study will involve a subset of the female animals that were previously studied. There will be the following animal groups, all exclusively raised and housed in outdoor colonies:

1. Female animals born between April 1-June 15 2008 (2008 females; n=30)
2. Female offspring of 2008 females (n=15)
3. Male offspring of 2008 females 8 (n=15)
4. Female animals born between April 1-June 15 2009 (2009 females; n=30)
5. Female offspring of 2009 females (n=15)
6. Male offspring of 2009 females (n=15)

To age-match the groups, the 2008 females will be studied during year one, and the 2009 females during year two. Male and female offspring from both groups of mothers will also be age matched.

Animals will be brought from their colony into the laboratory one time. While in the laboratory the animals will be sedated and undergo lung imaging studies to assess lung volumes and structure, and blood will be drawn for assessment of immune responses of red blood cells to microbial challenge, using ELISA assays, and for the epigenetic assays. The epigenetic assays will be performed using comprehensive nano-liquid chromatography tandem mass spectrometry. The investigators will also evaluate the medical histories of the animals that also participated in the earlier study to determine whether there is a relationship between the changes in lung and immune function

observed in the previous study and subsequent health. All tests proposed are minimally invasive. The research involves only blood samples and lung function tests.

The data will be initially assessed for whether or not it is normally distributed, and the investigator will then select standard parametric or non-parametric tests as appropriate.

### **III. STAFF COMMENTS**

The draft proposal was reviewed by Research Division staff. It was also sent to U.S. Environmental Protection Agency staff for review, and any additional comments will be presented to the committee at the meeting. The study is a natural follow-up to the results of the previous study. The study is well designed, and uses standard, well-accepted methods for both the scientific and statistical parts of the study. There is adequate statistical power. The investigators have proposed alternative, more sensitive, immune assay approaches that will be adopted should the red blood cell immune response in the offspring animals prove to be lower than expected. The change to lung imaging from the inhalational lung studies used in the previous project will provide a more comprehensive picture of lung health because in addition to providing lung volumes, it allows visualization of any changes in the lung's structure that could be attributable to the exposure. The budget is reasonable, but needs to be transferred to the standard agency format in the final version of the work plan. There are a few typos and other minor editorial points that should be corrected in the final version of the proposal.

### **IV. STAFF RECOMMENDATION**

Staff recommends the Research Screening Committee approve this proposal for a total amount not to exceed \$330,483, subject to inclusion of any changes and additions specified by the Committee.

## DISCUSSION OF A NEW RESEARCH PROJECT

ITEM NO.: II.3  
DATE: March 27, 2015  
PROPOSAL NO.: 2786-282

### STAFF EVALUATION OF A NEW RESEARCH PROPOSAL

**TITLE:** Greenhouse Gas Measurements at Walnut Grove Tower

**CONTRACTOR:** University of California, Davis

**PRINCIPAL INVESTIGATOR:** Marc Fischer, Ph.D.

**CONTRACT TYPE:** Interagency Agreement

**TOTAL AMOUNT:** \$200,000

**CONTRACT TERM:** 36 months

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For further information, please contact Dr. Abhilash Vijayan at (916) 324-0621.

### I. SUMMARY

The California Global Warming Solutions Act (Assembly Bill 32 or AB 32) requires ARB to monitor and regulate sources of emissions of greenhouse gases (GHG), and reduce GHG emissions to 1990 levels by 2020. Because inventory estimates of GHGs are uncertain, independent methods are valuable and necessary to evaluate the statewide emissions and ensure progress towards meeting the emission reductions goals. Atmospheric inverse modeling methods offer the potential to quantify and evaluate current GHG emissions using ambient measurements. The objective of this project is to provide a continuous long-term record of GHGs for Central Valley and the San Francisco Bay Area regions. This objective will be accomplished by continuous time series measurements of methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), and carbon monoxide (CO) with advanced research grade instrumentation, and every 2-3 day flask sampling for the above species, radiocarbon <sup>14</sup>CO<sub>2</sub>, and volatile organic compound (VOC) tracer measurements at the Walnut Grove tower. This project will deliver high-quality, post-processed data in support of the purpose of future inverse model analysis. In addition, the principal investigator will also provide a long-term analysis of the GHG trends in the California Central Valley and

San Francisco Bay Area regions over a 10-year period using the data from this project as well as two prior ARB contracts.

## **II. TECHNICAL SUMMARY**

### **Objective**

The objective of this project is to produce a continuous long-term record of relevant GHGs for the Central Valley and San Francisco Bay Area region; perform a long-term GHG trend analysis over a decadal data record, and deliver high-quality data in support of ARB's GHG monitoring network project and inverse modeling and validation efforts.

### **Background**

AB 32 requires ARB to monitor and regulate sources of emissions of greenhouse gases that cause global warming in order to reduce emissions of greenhouse gases, and to maintain and update California's GHG inventory to support the AB 32 program and track statewide progress. Current inventory-based estimates of GHGs are significantly uncertain, particularly for non-CO<sub>2</sub> gases, and highlight the importance of independent methods to the emissions and their mandated reductions. Atmospheric GHG measurements from networks of towers, when combined with analytical techniques such as inverse modeling estimations, can be used to quantify GHG emissions and help in the evaluation and improvement of the GHG inventories, and track regional and statewide progress in reducing emissions.

Atmospheric inverse methods, which estimate the surface emissions of GHGs using in-situ and remotely sensed GHG concentrations and modeled wind fields, have been widely applied at both global and regional scales to provide independent tests of GHG emission inventories. In general, the components of atmospheric inverse emission estimates are GHG measurements, an atmospheric transport model (including chemistry for global simulations), a priori estimates for GHG emissions and sinks or their correlation structure, and a statistical technique to minimize differences between measured and predicted GHG mixing ratios.

ARB operates a Statewide GHG Monitoring Network throughout the state with seven regional monitoring stations to measure the regional GHG concentrations throughout the state, track GHG trends in California, and help evaluate and inform the GHG

inventory to support the successful implementation of AB 32 programs. However, ARB does not currently have a monitoring location in the Bay Area/Sacramento region with sufficient capabilities to measure the region's emissions.

Dr. Marc Fischer has been operating a tall-tower GHG monitoring station near Walnut Grove (just south of Sacramento), and the station has the capability to measure real-time CH<sub>4</sub>, N<sub>2</sub>O, CO<sub>2</sub>, and CO concentrations. This station also has the ability to measure ambient GHG concentrations at tall heights, which is a critical component for robust measurement of emissions from a large regional footprint with confidence, and therefore represents a premier site for GHG measurements of unique value and for quantifying GHG emissions from a wide region of Northern and Central California. Over the years, Walnut Grove tower site has been a crucial part of ARB's GHG monitoring network program, and has been providing high temporal and spatial resolution GHG measurements for various inventory evaluation studies in the state. Without long term monitoring of CH<sub>4</sub>, N<sub>2</sub>O, CO<sub>2</sub> and CO data in the region, ARB will not have the appropriate tools for the evaluation of statewide GHG emissions and tracking statewide progress with the utmost precision and accuracy. Therefore, continued measurements at the Walnut Grove tower proposed here in the proposal are of high value for verifying the level of current regional GHG emission emissions released into the atmosphere, and help identify appropriate emission reduction measures in the future. In addition, the proposed project will also provide a long-term trend analysis of GHG emissions in the region over a 10-year period.

### **Proposal Summary**

The project proposal includes two main tasks, including: 1) Conduct multi-year GHG measurements/calibration; and 2) Data processing, calibration and delivery to ARB for inverse modeling, and a long-term analysis of the GHG trends in the California Central Valley and San Francisco Bay Area region.

**Task 1:** Conduct multi-year GHG measurements and instrument calibrations at Walnut Grove.

The objective of this task is to operate and maintain multiple trace gas analyzers at the Walnut Grove tower site to collect continuous records of CH<sub>4</sub>, N<sub>2</sub>O, CO<sub>2</sub>, and CO mixing ratios from 91 and 483 m heights above ground level. The trace gases will be measured

using a sampling and analysis system combining pumps, air driers, and gas analyzers. Briefly, air samples will be drawn continuously from the different heights on the tower, dried using a combination of condensing system and membrane driers (to a -33 °C dew point), and then are supplied to gas analyzers for CO<sub>2</sub> and CH<sub>4</sub> (Picarro 2301); and N<sub>2</sub>O and CO (LosGatos EP) measurements. Additionally, older instruments will provide redundant measurements for CO (Thermo Scientific TE48TC), and CO<sub>2</sub> (Licor LI-7000). To quantify and correct instrument drifts, offset and gain will be checked and corrected using gas standards.

Furthermore, roughly bi-daily flask samples will be taken from 91 m for analysis of all major GHG's, and associated tracers. The bi-daily flask sampling and analysis will continue through the LBNL/NOAA-ESRL collaboration. This task will be conducted on-site at the Walnut Grove tower by the PI.

**Task 2:** Data processing, calibration, trend analysis and delivery to ARB for inverse modeling.

- a) The goal of this task is to perform data calibration and quality control on all data collected at the Walnut Grove tower site to provide ARB with a three-year measurement record of continuous GHG species and NOAA-ESRL flask analyses of major GHG species and VOC tracers. To provide ongoing data processing and quality control for the Walnut Grove site, the PI will continue daily-to-weekly inspection and correction of problems, and quarterly quality control checks. In addition, final one-year data sets will be screened for quality assurance using NOAA flask sample analysis. Data screening will include time inspection of the mixing ratio time series to identify outlying events due to unexpected emission sources (e.g., CO from fires).
- b) The PI will also provide ARB with a long-term analysis of the GHG trends in the California Central Valley and San Francisco Bay Area region over a 10-year period using the data from this project as well data collected through prior research efforts at this site. The tall heights of the Walnut Grove tower increase the tower's measurement footprint, and can measure emissions from a large region of California Central Valley and San Francisco Bay Area region.

### **III. STAFF COMMENTS**

The committee received a copy of the draft proposal titled, “Continuation of Greenhouse Gas Monitoring in California.” The new title is “Greenhouse Gas Measurements at Walnut Grove Tower,” as it is more representative of the work being proposed in the project.

The draft technical proposal was reviewed by ARB staff from the Research Division and the Air Quality Planning and Science Division. The original proposal draft needed some work to clarify the technical approach and overall project timeline, data deliverables, and other minor technical issues. The length of record of deliverable data was expanded from three years to three and a half years, including the last six months of data in the form of raw data. This dataset will include one year of data that will have been collected at the station prior to the commencement of this project (June 2014 – June 2015), and two and a half year of new data that will be collected between July 2015 and December 2017.

The proposal complements ongoing efforts of ARB’s GHG Monitoring Network program. It continues a multi-year ambient measurements effort and data record at a crucial location representative of the GHG emissions of California Central Valley and San Francisco Bay Area region. The researchers will also provide a long-term analysis of the GHG trends in the California Central Valley and San Francisco Bay Area region over a 10-year period using the data collected from this project and data collected from prior research efforts at this site.

The proposal’s technical approach is technically sound and straight forward, and uses proven instrumentation, setup, and location. Furthermore, the proposed project provides crucial and highly valuable data to the statewide GHG monitoring effort.

We believe Dr. Fischer to be the best candidate for this research project as he will be able to provide consistency of both measurement methodology and location, ensuring the best possible continuous GHG dataset. Dr. Fischer has prior experience in both the methods as well as the specific location of measurement, and has an ongoing lease at the Walnut Grove tower. Dr. Fischer has previously conducted several GHG-related research projects for ARB and other agencies and has developed considerable expertise measuring GHGs.

#### **IV. STAFF RECOMMENDATION**

Staff recommends the Research Screening Committee approve this proposal for a total amount not to exceed \$200,000, subject to inclusion of any changes and additions specified by the Committee.

## DISCUSSION OF A NEW RESEARCH PROJECT

ITEM NO.: II.4  
DATE: March 27, 2015  
PROPOSAL NO.: 2787-282

### STAFF EVALUATION OF A NEW RESEARCH PROPOSAL

**TITLE:** Certification and In-Use Compliance Testing for Heavy-Duty Diesel Engines to Understand High In-Use NO<sub>x</sub> Emissions

**CONTRACTOR:** University of California, Riverside

**PRINCIPAL INVESTIGATORS:** Thomas D. Durbin, Ph.D.  
Kent C. Johnson, Ph.D.  
Georgios Karavalakis, Ph.D.

**CONTRACT TYPE:** Interagency Agreement

**TOTAL AMOUNT:** \$500,000

**CONTRACT TERM:** 24 months

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

#### I. SUMMARY

The State of California needs considerable reduction in oxides of nitrogen (NO<sub>x</sub>) emissions to meet ambient air quality standards for ozone and particulate matter (PM). To achieve some of the reduction, the NO<sub>x</sub> emission certification standards for heavy-duty diesel engines (HDDE) were reduced by 90 percent in 2010, and the in-use heavy-duty diesel vehicle (HDDV) compliance program (known as the "Not-To-Exceed," or NTE, standard) was implemented to control NO<sub>x</sub> and PM emissions over the full range of engine speed and load combinations commonly experienced in use. However, recent chassis dynamometer test studies of HDDVs show smaller reductions of in-use NO<sub>x</sub> emissions than expected based on their certification standards. These results raise questions about the effectiveness of the in-use HDDV compliance program in reducing NO<sub>x</sub> emissions. This proposed study will first review fundamental principles and purposes of current certification and in-use emission testing procedures, then conduct experiments featuring two selective catalytic reduction (SCR)-equipped HDDVs that involve collection of engine operation and emissions data from both chassis and engine

dynamometers, as well as on-road portable emission measurement systems (PEMS). The collected data will be analyzed to understand the differences between NO<sub>x</sub> emissions measured from model year 2010 or newer in-use HDDEs and the emissions obtained from the same engines during certification. The collected data will be also analyzed to evaluate the effectiveness of current and alternative in-use HDDV compliance requirements for control of NO<sub>x</sub> emissions. The results from this proposed study will be used to evaluate the effectiveness of current HDDE certification and in-use HDDV compliance procedures for meeting the ambient air quality standards for ozone and PM in California.

## **II. TECHNICAL SUMMARY**

### **Objective**

The objective of this research is to better understand the differences between NO<sub>x</sub> emissions measured from 2010 or newer in-use HDDEs under certification conditions on an engine dynamometer and the emissions measured from the same engines under in-use testing conditions either on-road or on a chassis dynamometer. The research will evaluate these differences via direct experimental measurements as well as a review of the literature and the theory behind the different methods of emission measurements. The results from this study will be used to evaluate the effectiveness of current HDDE certification and in-use HDDV compliance procedures for controlling in-use NO<sub>x</sub> emissions from HDDVs and to make suggestions regarding these procedures that could facilitate meeting the ambient air quality standards for ozone and PM in California.

### **Background**

The State of California has a number of regions that are out of compliance with national ambient air quality standards for ozone and PM. Although considerable progress has been made in reducing the relevant emissions and in improving air quality, further reductions in NO<sub>x</sub> emissions are still needed, especially from HDDVs, to meet the air quality standards. To achieve some of the reductions, the NO<sub>x</sub> emission standards for HDDEs were reduced by 90 percent in 2010, and the in-use compliance program was implemented in 2007 to control NO<sub>x</sub> and PM emissions over the full range of speed and load combinations commonly experienced in use. HDDEs are certified to meet emission standards before the engines are integrated into vehicle chassis for commercial use. Tests for HDDE certification are conducted on an engine-dynamometer over the

Federal Test Procedure (FTP) cycle that was developed to be representative of real-world HDDV driving patterns. However, recent studies for in-use HDDE emissions show smaller reductions in NO<sub>x</sub> emissions than expected compared with their certification standards. NO<sub>x</sub> emissions measured from 2010 in-use HDDVs over the Urban Dynamometer Driving Schedule (UDDS) cycle, a chassis-dynamometer cycle comparable to the FTP engine cycle, are substantially higher than the certification standard of 0.2 g/bhp-hr NO<sub>x</sub>. Additionally, studies show that a substantial fraction of vehicle activity and NO<sub>x</sub> emissions occurs outside the range of engine speed and load subject to NTE limits. Thus, it is uncertain how effective the NTE requirements are in reducing in-use NO<sub>x</sub> emissions. Given the importance of achieving reduction of real-world, on-road NO<sub>x</sub> emissions, it is important to investigate the differences between certification and in-use emissions, to understand the factors contributing to these differences, and to investigate the effectiveness of in-use compliance requirements in control of NO<sub>x</sub> emissions from HDDVs.

### **Proposal Summary**

A minimum of two 2010 or newer HDDVs, each equipped with diesel particulate filter (DPF) and SCR technologies, will be tested using three test methods: engine-dynamometer, chassis-dynamometer, and on-road PEMS. Testing will be conducted over a number of different cycles or driving conditions to evaluate a wide range of engine and vehicle operations. Test data collected from the measurement methods will be analyzed and compared. Differences in the theoretical principles, purposes, and characteristics of each test method will be evaluated. Based on findings from this study, the effectiveness of current HDDE certification procedures and in-use HDDV compliance procedures will be assessed.

- 1) Literature review: Investigators from the University of California, Riverside (UCR) will review theoretical principles, purposes, and characteristics of HDDE certification and in-use HDDV compliance procedures, and conduct comparative analyses of engine activities and emissions measured over the FTP and UDDS dynamometer cycles, as well as in-use on-road driving cycles.
- 2) Truck recruitment and test preparation: A minimum of two 2010 or newer HDDVs equipped with DPF and SCR aftertreatment technologies will be recruited. Engines

should be compliant with the 0.2 g/bhp-hr NO<sub>x</sub> certification standard, have been used under normal operating conditions, and have followed scheduled maintenance. An engine and vehicle inspection guide will be developed and the recruited trucks will be inspected with the guide before conducting any emission tests.

3) In-use and engine emission tests: Emission measurements will be sequentially conducted at a chassis-dynamometer, on the roads, at an engine-dynamometer, and finally at a chassis-dynamometer laboratories. A concurrent emission measurement with a PEMS will be conducted during the first chassis-dynamometer and engine-dynamometer tests to provide an independent confirmation of any emission differences observed.

- Chassis-dynamometer tests will be conducted over five dynamometer test cycles, including a UDDS, ARB-creep, ARB-transient, ARB-cruise, and high-speed cruise. Hot start tests will be conducted with a minimum of three repeats for each cycle, and cold start tests will be conducted a minimum of three repeats over the UDDS cycle.
- On-road PEMS tests will be conducted along three routes mimicking the chassis-dynamometer cycles of UDDS, ARB-creep, and ARB-cruise, or an on-road route including the characteristics of all three cycles, or both. In addition to the hot start tests, a minimum of three cold start tests will be conducted over a cycle mimicking the UDDS.
- Engine-dynamometer tests will be conducted over two standard engine-dynamometer cycles (the FTP and the ramped modal cycle - supplemental emissions test, RMC-SET), and over engine-dynamometer versions of five chassis-dynamometer cycles (UDDS, ARB-creep, ARB-transient, ARB-cruise, and high-speed cruise). The engine-dynamometer version of the UDDS will be derived from truck-specific engine torque, rpm and power collected during the chassis-dynamometer tests. The purpose of the engine dynamometer version of the UDDS is to compare emissions during chassis testing with the emissions during engine testing in order to see how closely the emissions match, and to see how emissions differ for the same engine and equivalent cycles between

the two platforms. In addition to three hot start tests for each cycle, a minimum of three cold start tests will be conducted over the FTP and UDDS cycles.

- Final chassis-dynamometer tests will be conducted over the five chassis-dynamometer cycles used for the first chassis-dynamometer tests. The purpose of this final-chassis-dynamometer testing is to bracket the engine testing, and verify that the engine and emission levels were not changed during the engine removal and reinstallation process.
- 4) Data analysis and recommendation: The investigators will analyze the data collected from the in-use and engine emission tests, compare engine activity and emissions over the test cycles, and evaluate the effectiveness of current HDDE certification and in-use HDDV compliance procedures for controlling in-use NO<sub>x</sub> emissions from HDDVs. The investigators will make suggestions regarding these procedures that could facilitate meeting the ambient air quality standards for ozone and PM in California.
  - 5) Meetings and Reports: There will be a kickoff meeting at the beginning of the project. Communications during this research will include regular and unscheduled briefings, as well as the contractual written quarterly reports on the technical and financial progresses. A draft final report will be provided six months prior to the end of the project, and comments on the draft will be incorporated into a final report. The investigators may present a Chair's Air Pollution Seminar on the completed project. All data, technical interim and final reports generated during the project will be made available to ARB in an electronic or other format that makes the data easily accessible. This will include the integrated and the modal data from each of the test runs.

### **III. STAFF COMMENTS**

The proposal was developed collaboratively between UCR investigators and ARB staff, and has been reviewed by staff in the Research and the Mobile Source Operation Divisions. Emission measurements from HDDEs and HDDVs with three different laboratory methods will greatly help understand the differences between NO<sub>x</sub> emissions from model year 2010 or newer in-use HDDEs and the emissions obtained from the same engines during certification. The measurements will help in evaluating the

effectiveness of in-use compliance requirements for control of in-use NO<sub>x</sub> emissions from HDDVs. Staff believes the expected findings from this research will be critical components for quantifying real-world NO<sub>x</sub> emissions from HDDVs and for developing air quality plans to meet the ozone and PM standards. The research concept was approved by the Board at the December 2014 Board meeting as part of the fiscal year 2015-2016 research plan. The team of investigators is very strong and has a great deal of experience in measuring emissions from engine-dynamometer, chassis-dynamometer, and on-road PEMS laboratories, and in analyzing HDDE and HDDV activity and emission data. ARB collaborated very successfully with this team at UCR on a number of related projects in the past. Results from this study will be published in peer-reviewed journals and through conference presentations.

#### **IV. STAFF RECOMMENDATION**

Staff recommends the Research Screening Committee approve this proposal for a total amount not to exceed \$500,000, subject to inclusion of any changes and additions specified by the Committee.

## DISCUSSION OF A NEW RESEARCH PROJECT

ITEM NO.: II.5  
DATE: March 27, 2015  
PROPOSAL NO.: 2788-282

### STAFF EVALUATION OF A NEW RESEARCH PROPOSAL

**TITLE:** Investigative Modeling of PM2.5 Episodes in the San Joaquin Valley Air Basin in Recent Years

**CONTRACTOR:** University of California, Davis

**PRINCIPAL INVESTIGATOR:** Michael Kleeman

**CONTRACT TYPE:** Interagency Agreement

**TOTAL AMOUNT:** \$199,928

**CONTRACT TERM:** 30 months

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

#### I. SUMMARY

The greatly decreased severity of air pollution events in California over the last 15 years has benefited human health, yet also presented new challenges for air quality modeling. Chemical transport models (CTM) that are used in State Implementation Plan development have not been able to completely adapt to the changing emissions and meteorological conditions. One of the results from this is that compared with events 10-15 years ago, CTMs underpredict nitrate concentrations by a much larger amount. To address this and other model shortcomings, this project will systematically address all potential causes for underpredictions in nitrate concentrations and correct them where possible. To accomplish this, two phases of the project are planned. An initial phase will investigate possible modeling biases in both reactive nitrogen emissions and meteorological fields through various comparisons with measurements. Based on the results of this work, the principal investigator and ARB staff will select and prioritize the most promising tasks for phase 2 from four hypotheses. These consist of corrections to biases in emissions of nitrate precursors, corrections to biases in meteorological fields, optimization of nitrate production conditions, and refinements to the spatial resolution for nitrate formation. Using an updated CTM, the researchers will simulate historical and

current air pollution episodes, which will then be used make final improvements to the model. Results from this work will include verified model inputs for CRPAQS, CalNex, and DISCOVER-AQ periods, a revised conceptual model for nitrate formation, and the incorporation and demonstration of a computationally efficient algorithm in a CTM. The techniques and model will be easily transferable to regulatory models such as CMAQ, which will improve ARB's modeling basis for SIP development.

## **II. TECHNICAL SUMMARY**

### **Objective**

The objective of the project is to improve the ability of CTMs to simulate particulate nitrate concentrations during contemporary air pollution episodes in California. The project will identify and correct shortcomings in emissions inputs, meteorological fields, and basic nitrate chemistry/processes that produce under predictions in nitrate concentrations. Two phases of the project are planned: an initial phase that will investigate emissions of reactive nitrogen species and associations between biases in predicted meteorological variables and nitrate concentrations; and a second phase in which the specific tasks from a set of four hypotheses will be chosen by the PI and ARB staff based on evaluation of results from phase 1 of the project.

### **Background**

Over the past 15 years, the severity and chemical composition of air pollution events has changed significantly. Overall, maximum concentrations of PM<sub>2.5</sub> have decreased and dominant species and prevailing meteorological conditions have shifted. Whereas previously CTMs were generally able to capture the buildup of nitrate over the high PM<sub>2.5</sub> concentration episodes, these models currently under-predict nitrate concentrations during contemporary episodes (and by a much larger amount in recent episodes). These shortcomings reflect the inability of the CTM to adapt to contemporary air pollution conditions and indicate the need for updates to the models before they can be used to design future emissions control strategies.

Efforts by the PI and ARB's Air Quality Planning & Science Division (AQPSD) staff to resolve poor model performance initially concentrated on meteorological parameter and emissions. This work has not provided significant improvements in performance, which suggests that other more fundamental problems need to be resolved. The proposed

research will explore all potential causes for nitrate under prediction in a systematic manner and correct them where possible.

In this respect, one of the areas that may offer improvements but that has remained largely unexplored is the possibility of optimal nitrate formation zones that are below the grid resolution of CTMs. Efficient nitration formation via the nighttime chemical pathway during winter events requires elevated concentrations of both ozone and  $\text{NO}_x$ . Because emissions have decreased in recent years, such optimal zones may have decreased in size compared with earlier years, possibly below the size of typical model grids. Finer spatial resolution in both vertical and horizontal directions may be needed to resolve these structures.

### **Proposal Summary**

The proposed project is divided into two phases. Phase 1 consists of two primary tasks which will determine the focus of Phase 2 of the project. The initial tasks consist of 1) comparing predicted with measured total reactive nitrogen concentrations to verify the total emissions (of reactive nitrogen, sulfur and ammonia) are approximately correct; 2) investigating any associations between biases in meteorological variables (wind speed, mixing depth, temperature, relative humidity, etc.) and biases in nitrate concentrations. In conjunction with the PI, staff from AQPSD will carry out some of these assessments. An interim report will be prepared based on findings from Phase 1; and a meeting between ARB staff and the PI will be held to determine the specific tasks to be carried out in Phase 2 of the work. These tasks will be selected and prioritized from the following four: 1) If total emissions of particulate nitrate precursors are biased, then emissions estimates will be adjusted to better describe spatial and temporal profiles; 2) If meteorological fields are biased in the model, then meteorological parameters will be improved (such as parameterizations of the boundary layer to remove biases in wind speed, mixing depth, relative humidity, etc.). If needed, diagnostic meteorological fields will be used as an alternative. 3) If evidence suggests that neither biases in emissions nor meteorological inputs cause under predictions in nitrate concentrations, then refinement of processes/mechanisms will be carried out; these include increased spatial resolution to better resolve zones of optimal nitrate production in the presence of steep gradients, revision of chemical reactions leading to nitrate formation based on the latest scientific results, and refinement of thermodynamic

models. 4) Historical (CRPAQS) and recent (DISCOVER-AQ, CalNex) air pollution episodes will be simulated with the latest inputs determined above. These simulations will determine if model performance is improved for both historical as well as contemporary air pollution episodes (further refinements in the model may be suggested through these comparisons).

### **III. STAFF COMMENTS**

ARB staff from AQPSD and the Research Division reviewed this proposal and is very enthusiastic about the scope of work and projected outcome from this project. The work should improve ARB's ability to model high nitrate PM<sub>2.5</sub> events in California across a wide range of years to the present, which will translate into a much better ability to carry out SIP development in future years. Professor Kleeman has worked with ARB on many different source apportionment and modeling studies and has a very good record for both producing useful results and keeping projects on schedule and within budget. As well as bringing extensive knowledge of air quality in California and a deep set of skills in air quality modeling to this project, he brings a powerful and flexible computing environment, consisting of a cluster of 400 nodes forming a distributed memory parallel computer (one of the largest in the UC system that is operated by a single research group). Commercial costs alone for the processing power needed for this work would run over \$400,000.

### **IV. STAFF RECOMMENDATION**

Staff recommends the Research Screening Committee approve this proposal for a total amount not to exceed \$199,928, subject to inclusion of any changes and additions specified by the Committee.

## DISCUSSION OF A DRAFT FINAL REPORT

ITEM NO.: III.1

DATE: March 27, 2015

CONTRACT NO.: 13-313

[Link to Report](#)

### STAFF EVALUATION OF A DRAFT FINAL REPORT

**TITLE:** Technical Analysis of Vehicle Load Reduction Potential for Advanced Clean Cars

**CONTRACTOR:** Control-Tec, LLC

**PRINCIPAL INVESTIGATOR:** Mr. Gregory Pannone

**CONTRACT TYPE:** Standard Agreement

**TOTAL AMOUNT:** \$162,120

**CONTRACT TERM:** 18 months

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

#### I. SUMMARY

Reducing vehicle road load through greater use of improved aerodynamic designs, low rolling resistance tires, and mass reduction can contribute to tailpipe greenhouse gas (GHG) emission reductions to varying degrees. This research analyzed vehicle attribute data to identify the configurations within the 2014 model year using best available or best-in-class load-reducing technologies and determined the impact on the overall vehicle fleet if all vehicles utilized such technologies. These findings were used to project potential tailpipe carbon dioxide (CO<sub>2</sub>) emission reductions from the light-duty fleet. Assuming that all vehicles adopt load reduction technologies and strategies already demonstrated in today's better performing vehicles, it is estimated that a reduction in tailpipe CO<sub>2</sub> emissions of 10.4 percent is achievable. The results of this study will be useful for producing a technical assessment of the feasibility for producing vehicles complying with the Advanced Clean Cars program in future model years.

## II. TECHNICAL SUMMARY

### Objective

Stringent GHG emission standards may require vehicle manufacturers to increasingly utilize load-reduction strategies such as aerodynamic drag improvements, reduced tire rolling resistance, and mass optimization to comply. The objective of the research is to determine to what extent model year 2014 vehicles have already adopted some level of these technologies and the potential reduction of fleet-wide CO<sub>2</sub> emissions if all vehicles achieved the load attributes demonstrated by the better performing model year 2014 vehicles. The scope of the research includes all light-duty vehicles and benchmarks and projects results from the regulated drive schedules.

### Background

ARB recently approved the Advanced Clean Cars program which requires the new vehicle fleet to meet increasingly lower fleet average tailpipe CO<sub>2</sub> emission standards. Greater penetration of load-reduction technologies, such as improved aerodynamic designs, low rolling resistance tires, mass reduction, and reduced accessory loads, is likely to be a core component of auto manufacturers' compliance strategies. Reducing vehicle road load through these strategies contributes to GHG emission reductions by reducing the energy required to propel the vehicle. Reducing vehicle road load may also allow for a downsized powertrain while maintaining vehicle performance characteristics, which may in turn reduce emissions further; or for electric-drive vehicles, reduced vehicle load can result in lower energy storage requirements and vehicle costs.

Lutsey (2012)<sup>1</sup> evaluated the annual U.S. EPA model-by-model fuel economy and carbon dioxide emission certification data and found wide variation in aerodynamics, rolling resistance, and powertrain efficiency that suggests significant potential improvement in future models. Previous ARB-sponsored research by Lotus Engineering validated the ability to reduce vehicle mass by over 30 percent without compromising safety, and joint modeling efforts by ARB and the U.S. EPA for future light-duty vehicle GHG emission standards found feasible and cost-effective reductions of up to 20 percent for vehicle mass, tire rolling resistance, and aerodynamic drag. Continued evaluation of the potential benefits of load reduction strategies will help ARB to assess

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<sup>1</sup> Lutsey, N. (2012) "A technical analysis of model year 2011 US automobile efficiency," *Transportation Research Part D*, 17(5): 361-369.

the technical feasibility and associated costs for advanced technology vehicles in future model years. Basing this analysis on existing technologies found on vehicles in commercial production produces some level of assurance that these technologies can be adopted without compromising vehicle safety.

### **Project Summary**

The contractor conducted a literature review of load-reduction technologies and strategies that are in the current light duty fleet. They identified and described data sources that contain sufficient detail in vehicle attributes for the 2014 model year that allowed them to assess, calculate, or infer vehicle load of individual vehicle configurations. Using these data sources, they identified which vehicle configurations in the fleet are using non-mass load-reduction technologies, materials or designs, and determined vehicle class-specific technologies are best-in-class. Additionally, they developed a metric for “mass efficiency” of a vehicle to determine the most mass efficient vehicles in the fleet. The data were analyzed and input into road load and mass models and were also assembled into a project-specific website that provides information on individual vehicles and fleet projections with ARB.

Using the vehicle simulations, the fuel consumption, CO<sub>2</sub> emissions, and acceleration performance of each vehicle model and powertrain sub-configuration was determined to establish a baseline. The best-in-class performance of each load attribute was then applied to all vehicle models and the simulations were repeated to determine the change in fuel consumption, tailpipe CO<sub>2</sub> emissions, and acceleration performance. The lower vehicle loads would result in improved acceleration performance and a greater driving range from the on-board energy storage. The final evaluation, therefore, included reducing the size of the power source (e.g., engine) and the on-board energy storage to match the baseline acceleration and driving range. All fuel consumption and CO<sub>2</sub> emission results were reported for the regulated drive cycles only.

### **III. STAFF COMMENTS**

The draft final report has been reviewed by staff in the Emissions Compliance, Automotive Regulations and Science (ECARS) Division and staff from the U.S. EPA.

This report reflects a thorough analysis of performance levels achieved by load reduction technologies currently used in the light duty fleet. It identifies performance levels achieved by the best-in-class available load reduction technologies, and then estimates the improvement in fleet-wide fuel economy that could be achieved if all of the light duty fleet adopted the best in class load reduction technologies. Overall this analysis provides valuable input for the Mid-term Review of the Advanced Clean Cars regulation, and will significantly help ARB shape light duty vehicle policy going forward.

#### **IV. STAFF RECOMMENDATION**

Staff recommends the Research Screening Committee approve 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: March 27, 2015

CONTRACT NO.: 12-313

[Link to Report](#)

### STAFF EVALUATION OF A DRAFT FINAL REPORT

**TITLE:** Evaluating the Benefits of Light Rail Transit

**CONTRACTOR:** University of California, Irvine

**PRINCIPAL INVESTIGATOR:** Doug Houston, Ph.D.

**CONTRACT TYPE:** Interagency Agreement

**TOTAL AMOUNT:** \$200,000

**CONTRACT TERM:** 26 months

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

#### I. SUMMARY

Senate Bill 375 (SB 375) requires Metropolitan Planning Organizations (MPOs) in California to develop a Sustainable Communities Strategy that demonstrates how they will meet regional greenhouse gas reduction targets set by ARB. The introduction and expansion of light rail transit (LRT) systems and the densification of communities living around LRT stations are among the strategies being considered and pursued by regions as they work toward SB 375 goals. However, the regional travel demand forecasting models used by MPOs in their planning process are limited in their ability to accurately evaluate the impact of transit investment and transit-oriented development projects on travel demand. This research project implemented the first ever longitudinal, experimental-control, before-after evaluation of the impact of a light rail transit investment in California on travel behavior and the active transportation co-benefits for nearby residents. This project built upon an existing study that collected baseline data on travel behavior for 248 households in and near the Expo Line corridor in south Los Angeles. Due to substantial co-funding to support the second phase of data collection, this project supported a third phase of data collection, which allowed for a rare longitudinal look at travel behavior. The results of this research provide insight into

whether and to what extent light rail transit investments can support the goals of SB 375.

## **II. TECHNICAL SUMMARY**

### **Objective**

The objective of this study is to advance our understanding of the impact of light rail transit through time on the travel behavior of local residents, including travel mode, trip distance, and physical activity levels. In the course of this evaluation, the influence (effect size) of neighborhood land uses, individual and household socio-demographics, and individual attitudes and perceptions on the relationship between LRT and travel behavior was analyzed. This study also examines the issue of self-selection to see if the travel impacts of new compact, transit-oriented strategies are influenced by new residents who relocate from outside the area because of their preference to live in denser, transit-accessible areas.

### **Background**

The introduction and expansion of LRT systems and the densification of communities living around LRT stations are among the strategies being considered and pursued by regions as they work toward SB 375 goals. For instance, the Southern California Association of Governments (SCAG) region's recently adopted 2012-2035 Regional Transportation Plan/Sustainable Communities Strategy calls for investment in public transportation and directs substantial development and densification in High-Quality Transit Areas—areas within a half mile of well-served transit stops. In alignment with this goal, the Los Angeles Metropolitan Transportation Authority's long-range plan commits funds to six new LRT lines over the next decade. Other California cities and regions are also considering new LRT systems or expanding existing ones as strategies to reduce vehicle demand. While these strategies are being pursued, the impact that transit investment and transit-oriented development projects have on travel demand and co-benefits remains poorly understood. This study evaluates whether or not, and to what extent, LRT investment in California can support the goals of SB 375 and regions' Regional Transportation Plans/Sustainable Communities Strategies.

## **Methods**

This study's research approach adopts, as closely as possible, a classical controlled-experiment design to evaluate the longitudinal impacts of LRT on travel impacts. This design allows for the control of exogenous factors and allows for a more robust understanding of impacts through time. Researchers collected travel data from "experimental" households located near new transit stations and "control" households that were not systematically different except for not being proximate to a new station. Travel data was collected from these households at the same time of year at three points in time: before the stations opened in spring 2012, approximately a half year after it opened (Fall 2012), and a year and a half after the station opened (Fall 2013). A 7-day survey protocol, supplemental GPS tracking, and accelerometer data were used to collect detailed information on travel behavior. In addition, "new resident" households were recruited who moved to the area since LRT Expo Line service began. The travel behavior of these residents was compared to the travel behavior of core resident households to evaluate if their travel patterns differed from longer-term residents. Lastly, neighborhood characteristics and household socio-demographic data were correlated with travel data to see how it related to travel behavior.

## **Results and Conclusions**

This study found that households living within walking distance (1km) of a new Expo Line light rail station drove on average 11 vehicle miles less each day than control households. This reduction in travel demand was likely due to a reduction in average car trip length. In addition, the study found this reduction right after the stations opened, as well as a year and a half after stations' opening. While living near a station changed car travel behavior, living near the Expo station was not associated with a statistically significant change in walking or bicycling travel. The analysis of new residents that moved in after the station opened found that new residents were younger and had higher rental rate and income than the longer-term residents. These new residents differed slightly in their travel behavior as well. They drove 8-10 vehicle miles more each day and took longer car trips compared to longer-term households near a station, but their rail ridership rates were more than double that of their longer-term counterparts.

### III. STAFF COMMENTS

This project has received co-funding from the UC Transportation Center, the UC Sustainable Transportation Program, and the Haynes Foundation, reflecting the interest and relevance of this study. The draft final report was reviewed by staff in ARB's Research Division, the Air Quality Planning and Science Division, and a representative from the Los Angeles County Metro (the major operator of bus and rail service in Los Angeles County), a program manager at SCAG, and a transportation engineer with the Division of Research at the California Department of Transportation. Peer reviewers provided suggestions to shorten the discussion in some sections, expand the discussion in other areas, and improve several of the figures. In particular, peer reviewers suggested expanding the discussion of the results to further explain the differences in behavior from new and longer-term residents; households within walking distance reduced their vehicle miles travelled (VMT) by 11, but newer residents show the opposite trend of increasing VMT by 8-10. One peer reviewer suggested adding some discussion about the underreporting rate by new residents and the lack of using mobile tracking devices with this population; does this suggest that the new residents' 8-10 VMT increase is even higher? Another peer reviewer suggested that the Principal Investigator add some discussion about the difference in employment rates between the longer-term residents and the new residents. Does the lower employment rate (67 percent) for longer-term residents explain the 11 VMT less per day if more people are not working in the core versus new residents that had a much higher (97 percent) employment rate? Another peer reviewer acknowledged that much care and thought clearly went into the experimental research design, but because of the relatively small sample size in the before- and after- survey, it draws a couple of conclusions that would greatly benefit from having a larger sample size over a longer period or a completely different methodological approach.

Staff communicated these comments to the research team, which updated the draft final report to address all of the suggestions. As requested, the research team corrected and supplemented the writing where noted throughout the report. They added additional graphical representation of the differences between experimental and control households across waves. Finally, the research team expanded the discussion section to provide more interpretation of the results and a more thorough discussion of the

strengths and weaknesses of the study. Staff has no additional concerns or issues regarding the draft final report at this time.

Overall, the research fits neatly within the published research on transit investment and travel behavior. Although the study has some limitations, acknowledged by the authors, it is the first before-and-after evaluation of a major light rail transit investment in California, and as such contributes significantly to our understanding of the benefits of light rail transit. This research provides an important evaluation of how LRT transit investment plays out in the real world.

#### **IV. STAFF RECOMMENDATION**

Staff recommends the Research Screening Committee approve 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.