STATE OF CALIFORNIA

AIR RESOURCES BOARD

MEETING OF THE

RESEARCH SCREENING COMMITTEE

October 3, 2014
9:00 a.m.

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

State of California
AIR RESOURCES BOARD

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

October 3, 2014
9:00 a.m.

AGENDA

I. Approval of Minutes of Previous Meeting:

July 17, 2014 meeting

II. Discussion of a New Research Project:

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

III. Discussion of Draft Final Reports:

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

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

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

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

IV. Other Business:

1) Update on 2015/2016 Annual Research Plan

State of California
AIR RESOURCES BOARD

Research Screening Committee Meeting
Cal/EPA Headquarters Building
1001 I Street
Conference Room 710
Sacramento, California 95814
(916) 445-0753

July 17, 2014
10:00 a.m.

MINUTES

RSC Members in Attendance via teleconference

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

The Research Screening Committee (RSC or Committee) convened the meeting at 10:00 a.m. The minutes of the May 30, 2014 meeting were approved.

I. New Research Projects

1) "Characterization of PM2.5 Episodes in the San Joaquin Valley Based on Data Collected During the NASA DISCOVER-AQ Study in the Winter of 2013," $200,000, University of California, Davis, Proposal No. 2778-280

   The Committee found that the proposal addressed all concerns.

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

   The Committee approved the proposal.

2) "The Dynamics of Plug-in Electric Vehicles in the Secondary Market and Their Implications for Vehicle Demand, Durability, and Emissions," University of California, Davis, $300,000, Proposal No. 2779-280

Staff informed the Committee that ARB staff has permission to use DMV data to generate mailing addresses for buyers of used plug-in vehicles that will be surveyed in this project, and that they believed the researchers had addressed the concerns that the Committee raised at the May 30, 2014 meeting when an earlier draft of this proposal was initially reviewed.

A committee member commented that Task 4 was vague and that they wanted clarification that the data would provide the information necessary for the analysis, wanted further explanation of how the data variables mapped to the modeling that would be done, and wanted a clearer discussion of what hypotheses would be tested in this research. Staff will request that the researchers revise the proposal to address these comments.

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

The Committee approved the proposal. Forman Williams abstained from voting.

The meeting adjourned at 10:18 a.m.

DISCUSSION OF A NEW RESEARCH PROJECT
ITEM NO.: II.1
DATE: October 3, 2014
PROPOSAL NO.: 2782-281

STAFF EVALUATION OF A NEW RESEARCH PROJECT

TITLE:	Collection of Tractor-Trailer Activity Data
CONTRACTOR:	University of California, Riverside
SUBCONTRACTOR:	R.L. Polk
PRINCIPAL INVESTIGATORS:	Kent Johnson, Ph.D. Kanok Boriboonsomsin, Ph.D. Georgios Karavakalis, Ph.D. Thomas Durbin, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$500,000
CONTRACT TERM:	24 months

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

I. SUMMARY

In order to meet the greenhouse gas (GHG) emission reduction goals specified in California's Global Warming Solutions Act of 2006 (Assembly Bill 32, or AB32), GHG emission reductions are needed from heavy-duty tractors (HDT). The Tractor-Trailer GHG regulation adopted in 2012 was one of the discrete early action measures by the ARB to contribute to the goals of AB 32. The regulation applies to tractors pulling 53-foot or longer box trailers, and requires them to be equipped with aerodynamic technologies and low rolling resistance tires, but does not apply to other trailer types. The objective of this project is to investigate potential benefits of extending the regulation to other trailer types (e.g., flatbeds, tankers, etc.) and box trailers shorter than 53 feet. This objective will be accomplished by collecting tractor and trailer 'activity' data (e.g. vehicle miles traveled, average speed, etc.) using the following methods: 1) conducting tractor-trailer owner fleet surveys, and 2) collecting tractor-trailer activity data using on-board data loggers, followed by analysis of survey and data logger

activity data. Results will support the development of second-generation GHG control measures for HDT trailers.

II. TECHNICAL SUMMARY

Objective

The objective of this project is to investigate the potential benefits of extending the current HDT GHG aerodynamic technologies regulation for 53-foot box trailers to include other trailer types such as flatbeds, tankers, etc., and box trailers shorter than 53 feet in length. This objective will be accomplished by determining the vehicle 'activity' patterns such as daily and annual vehicle miles traveled (VMT), average speeds, etc., for selected candidate trailer types.

Background

The ARB regulation is intended to reduce GHG emissions from heavy-duty tractors (HDT) by reducing the load on the engine by reducing trailer aerodynamic drag and tire rolling resistance. In order for aerodynamic technologies to work most effectively to reduce aerodynamic drag, vehicle speed is a critical parameter since drag is proportional to the square of the vehicle's speed, and maximum benefits occur at higher vehicle speeds, such as highway cruise operation. Because of this the GHG regulation focused on long-haul trucking operation which accrues high annual vehicle miles traveled.

It is possible that similar GHG benefits may be obtained from different trailer types such as 'pup' trailers, 48-foot or shorter trailers, flatbed trailers, tankers, etc., but there are little to no data available about the impacts of aerodynamic technologies on HDT and trailers that operate under non-extended-highway-cruise conditions. Hence, data is needed to assess the potential benefits of aerodynamic technologies for trailer types and vehicle operating conditions beyond those included in the current GHG regulation.

Proposal Summary

The project proposal includes three tasks, including: 1) trailer fleet surveys of activity; 2) on-vehicle data logging; and 3) data analyses and reporting. The contractor will utilize tractor and trailer registration information obtained from subcontractor R.L. Polk to

determine trailer populations, and to obtain tractor and trailer owner contact information for administering the fleet surveys. CE-CERT will prepare a technical memorandum for review and approval by ARB staff before beginning each task.

Task 1 - Fleet surveys

ARB staff will provide the contractor with a list of four to six trailer types to be studied during the project. Using this list, CE-CERT will conduct the trailer fleet owner surveys seeking information about VMT and average speed for specific trailer types. This task consists of five subtasks: 1) development of fleet survey questionnaire; 2) survey administration; 3) solicitation of fleets for participation in data logging task; 4) analysis of survey data; and 5) selection of fleets for data logging. As noted above, Polk data will be used for this task to identify owners of trailers of interest. The goal is to obtain a minimum of 30 survey responses for each of up to six trailer categories.

Task 2 - On-Vehicle Data logging

This task will be accomplished by collecting data from data loggers equipped with Global Positioning System (GPS) receivers placed on selected tractors, and from existing trailers equipped with GPS receivers. CE-CERT will procure data loggers capable of collecting GPS data, and for a subset of data loggers, engine parameter data from the vehicle computer. These data loggers will be installed on selected vehicles to collect real-time activity data for a time duration, still to be determined, but expected to range between one and six months, depending on how the tractors-trailers are used. The data loggers will be deployed in fleets throughout the state and nationally. In addition, CE-CERT will also download vehicle speed data stored in the engine ECM. Surveys asking about trailer use will supplement the data logger data collection. The goal is to perform a total of 180 data logger exchanges for up to six trailer types.

Task 3 - Data analysis and reporting

CE-CERT will handle data processing, protecting fleet owner identities as necessary, and will address GPS data collection issues such as GPS signal drop out by filtering, data gap filling, and map matching. Subsequent to data processing, CE-CERT will conduct data analyses for each trailer type, determining average speeds, speed

distributions, vehicle miles traveled, etc. Data will be summarized and reported in the draft final report.

III. STAFF COMMENTS

The original project concept included wind tunnel testing, possibly computational fluid dynamics (CFD) modeling, and vehicle testing, in addition to activity data collection, but the project scope was reduced to focus only on tractor-trailer activity data collection. In the event that the activity data collected by this project identifies suitable candidate trailer types for GHG savings through the use of aerodynamic devices, wind tunnel testing, CFD modeling, etc., could be performed in a separate project.

The draft proposal was reviewed by staff from ARB's Mobile Source Control, Air Quality Planning and Science, and Research Divisions; the current draft proposal includes staff recommended changes.

Drs. Johnson and Durbin have previously conducted HDT-related research projects for ARB, the U.S. Environmental Protection Agency, the Engine Manufacturers Association, and other clients, and have developed considerable experience testing and collecting data from HDTs. Most recently (2013), Dr. Johnson successfully completed two off-road diesel equipment emissions test projects for ARB regulatory and emissions modeling staff.

The project will rely on tractor and trailer registration data obtained from R.L. Polk for most of the 48 contiguous states. The Polk data will consist of both tractor and trailer description information (manufacturer, model, etc.), as well as owner contact information. The population data can simply be tallied (and adjusted for attrition) to obtain population totals, while the owner contact information will be used to administer the surveys. Per agreement with Polk, the Polk-provided data to UC Riverside will have a specified lifetime (one or two years), after which time, they will be destroyed.

The revised proposal is considered to be responsive to ARB's project goals to collect information and activity data about additional trailer types that might be candidates for a second generation of the GHG regulation for HDT trailers.

IV. STAFF RECOMMENDATION

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

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: III.1
DATE: October 3, 2014
CONTRACT NO.: 10-320
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Evaluation of Pollutant Emissions from Portable Air Cleaners
CONTRACTOR:	Lawrence Berkeley National Laboratory
PRINCIPAL INVESTIGATOR:	Hugo Destaillats, Ph.D.
CONTRACT TYPE:	Standard Agreement
TOTAL AMOUNT:	$400,000
CONTRACT TERM:	42 months

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

I. SUMMARY

Portable air cleaners using newer technologies can generate primary and secondary emissions, such as formaldehyde, fine and ultrafine particles (UFP), and highly reactive oxygen species (ROS), such as hydroxyl radicals, which may lead to poor indoor air quality (IAQ) and associated health effects. In this study, the investigators measured primary emissions and secondary reaction byproducts from six air cleaners, including three photocatalytic oxidation (PCO) devices, a plasma generator, a ceramic heater/ionizer, and an antimicrobial heating device. Testing to assess their removal efficiency for volatile organic compounds (VOC) and particulate matter (PM) was conducted in a chamber first under clean air conditions and then challenged with VOC. Some of the tested devices were found to have significant removal efficiencies for some indoor air pollutants, while others were found to emit high levels of ozone, several VOC (e.g. toluene) as primary emissions, and to generate secondary byproducts, such as formaldehyde. In clean air, four of the devices showed measureable net VOC emissions. Devices that are intended to remove VOC removed just 8 percent to 29 percent of the VOC present. Only a PCO equipped with a HEPA filter and the

plasma device removed PM, and ROS emissions were measureable but low. The investigators also used chamber-derived emission rates to model typical indoor levels and to assess occupant exposure by comparing predicted levels to California health-based standards. They found that most emitted VOC were below health-based exposure standards, but in one modeling scenario, hazardous levels were exceeded for ozone, formaldehyde, and benzene. This research will help ARB determine whether there are any unhealthful emissions or performance concerns that need to be addressed in newer technology air cleaners. In addition, this research shows the need for the development of appropriate engineering controls to reduce the emissions of these pollutants and for the development of appropriate testing standards to assess hazardous air cleaner emissions other than ozone.

II. TECHNICAL SUMMARY

Objective

The objective of this study was to investigate, under realistic indoor operating conditions, primary and secondary emissions from portable air cleaners that use emerging technologies and to evaluate their potential impact on indoor air quality. Specifically, the investigators: 1) selected, in consultation with ARB staff, six portable air cleaners with a market presence in California; 2) developed test protocols that took into consideration the particular features and differences among the selected models; 3) characterized their primary and secondary emissions under typical indoor operating conditions in a test chamber; and 4) evaluated the potential impact of those emissions on indoor air quality and health using indoor air modeling and comparison to California health-based standards.

Background

Conventional technology air cleaners include pleated fiberglass or material filter devices; intentional ozone generators (OG), which purposely emit large quantities of ozone; and electrostatic precipitators (ESP) and ionizers, which usually emit little ozone but may produce substantial amounts of ozone. In 2007, ARB approved a regulation to limit ozone emissions from portable air cleaners. Since then, the portable air cleaner market has grown substantially, and air cleaners that incorporate newer technologies are now available and are popular choices for consumers. Several new products

combine new technologies that have not been well-studied, such as photocatalytic oxidation, with conventional technologies in an integrated device. PCO devices rely on oxidation of VOC that are in contact with a titanium dioxide catalyst irradiated with ultra violet light. While ozone emissions remain a concern, formaldehyde, other partially oxidized VOC, highly reactive oxygen species (ROS) such as hydroxyl radicals, and particles may be generated as undesired primary and secondary emissions and byproducts of the chemical processes taking place inside and in the air around such air cleaner units. As new technology devices continue to capture a growing market share, this study provides valuable information to evaluate potential indoor air quality and health impacts of these new generation devices.

Proposal Summary

The investigators assessed primary and secondary pollutant emissions from six portable air cleaners that included three PCO devices: one included HEPA filtration, another produced hydroxyl radicals, and the third produced high levels of ozone. The remaining three air cleaners consisted of a plasma generator, a ceramic room heater with an ionizer, and an antimicrobial heating device. The primary emissions from the devices were measured in a 20-m^3 stainless-steel environmental chamber under clean air conditions (Phase 1) and then each was challenged with a mixture that contained 11 VOC typically found indoors (Phase 2). Samples were taken from the chamber during periods with the air cleaner turned off and turned on, and emissions were determined using a mass-balance model. Emissions of volatile carbonyls, VOC, ozone, and ultrafine particles (UFP) were determined using: dinitrophenyl hydrazine (DNPH)-coated silica cartridges that were subsequently extracted and analyzed by liquid chromatography, sorbent tubes that were analyzed by thermal desorption/gas phase/mass spectrometry, a photometric analyzer, and a water-based condensation particle counter, respectively. In addition the researchers developed three methods to sample and analyze ROS that relied on fluorometric probes. For each air cleaner, ROS samples were collected in an impinger filled with a buffer and mixed with reactants to form a fluorescent byproduct that was analyzed spectrophotometrically using a fluorimeter.

Some of the air cleaners were found to have significant removal efficiencies of a sub-set of indoor pollutants, while others were found to emit high levels of ozone and several VOC as primary emissions or secondary byproducts. Very high ozone emissions were observed for one PCO device (up to 14 mg/hr), and measurable ozone emissions for the plasma air cleaner (up to 0.35 mg/hr). Two devices were found to remove UFP, including one PCO device with a HEPA filter and the plasma air cleaner. However, a significant amount of UFP were also generated by the PCO device that emitted the highest levels of ozone in this study; in the presence of ozone-reacting VOC, this device yielded chamber concentrations of 3 x 103 particles per cm^3, corresponding to an estimated secondary organic aerosol yield of 1-5 percent. For VOC, under clean air conditions, only one PCO device reduced VOC in the chamber, and four out of the six devices showed measurable net emissions; in the presence of the VOC challenge, four out of the six devices removed a measurable amount of VOC, and the other two had net emissions. Formaldehyde was produced as a secondary byproduct of two of the three PCO devices and the plasma air cleaner, with emission rates between 25 and 33 µg/hr. The detection and quantification limits of three ROS sampling methods developed in this study were in good agreement with similar methods showed in prior studies, and the reproducibility for each method was fairly good (< 7 percent). Within the sensitivity of the methods, no increase in ROS concentrations was detected during operation of the air cleaners, except one PCO device with the highest ozone emissions, for which the reaction of ozone with VOC led to the formation of measureable levels of ROS. The investigators also used chamber-derived emission rates to model typical indoor levels and to assess occupant exposure by comparing predicted levels to California reference exposure levels and Proposition 65 risk levels. They found most emitted VOC were below health-based exposure standards, but in one modeling scenario, hazardous levels were exceeded by ozone, formaldehyde, and benzene.

III. STAFF COMMENTS

Electronic copies of a preliminary draft final report were provided for review and comment to staff of ARB's Research Division. The current draft final report has addressed staff's main comments, and the laboratory work and content of the report meet the contract requirements.

This study has identified some IAQ or health concerns that may need to be addressed for newer air cleaning technologies, specifically their potentially harmful primary and secondary emissions. These are a particular concern because air cleaners are often purchased in an effort to address asthma and allergy symptoms in sensitive groups of the population such as children, and effective air cleaners should clean the air, not emit contaminants. This research shows the need for the development of appropriate engineering controls for PCO and other types of air cleaning devices, in order to reduce the emissions of pollutants identified by this study. These results also indicate the need for the development of appropriate testing standards to assess other hazardous air cleaner emissions in addition to ozone.

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: October 3, 2014
CONTRACT NO.: 09-340
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	On-Road Measurement of Emissions from Heavy-Duty Diesel Trucks; Impacts of Fleet Turnover and ARB's Truck and Bus Rule
CONTRACTOR:	University of California, Berkeley
PRINCIPAL INVESTIGATORS:	Robert Harley, Ph.D. Tom Kirchstetter, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$300,012
CONTRACT TERM:	60 months

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

I. SUMMARY

In the absence of regulation, drayage trucks tend to be older vehicles with little or no emission controls. These vehicles congregate near ports and rail yards, and emit large amounts of smog forming nitrogen oxides (NO_X) and particulate matter (PM), impacting nearby communities by contributing to many adverse health effects, including asthma, cancer, and premature deaths. The Statewide Drayage Truck aims to reduce emissions from drayage trucks operating at major freight-handling facilities such as ports and rail yards by prohibiting the pre-1994 model year (MY) engines from entering such facilities after December 31, 2009. Phase 1 of the regulation also required use of diesel particle filter (DPF) emission control systems on all MY 1994-2006 and later engines; this requirement was phased in over a period extending from December 31, 2009 to December 31, 2012. Phase 2 of the regulation then required that all engines exceed MY 2007 California or Federal emission standards by December 31, 2013.

To assess the effectiveness of fleet modernization rules and DPF retrofits on emissions from in-use trucks, field measurements of truck emissions near the Port of Oakland were performed during 2011 and 2013 using high time resolution (1 Hz or faster) instrumentation to distinguish the exhaust plumes of individual trucks. Black carbon (BC) emissions were measured as an indicator of PM emissions. This study adds to an existing record of on-road emissions data for drayage trucks measured at the same site in 2009 and 2010. The results show that diesel emissions near the Port of Oakland decreased by 76 percent ±22 percent for BC and by 53 percent ±8 percent for NO_X from 2009 to 2013. The study also showed that while BC and NO_X emissions have decreased near the Port of Oakland, both nitrogen dioxide (NO_2) concentrations and NO_2/NO_X ratios increased due to the catalysts used in the DPF's. The fleet average NO_2 emissions will eventually be reduced as trucks equipped with selective catalytic reduction (SCR) systems are introduced at the Port in coming years, but it will take time because the drayage rule doesn't require MY2010 compliant engines until December 31, 2022.

II. TECHNICAL SUMMARY

Objective

This study was conducted to characterize emissions from the heavy-duty diesel fleet near the Port of Oakland. It builds on previous work of the investigators by adding two new field measurement campaigns. The major objective of the study was to quantify emissions reductions over a course of multiple years by:

- Developing fuel based emission factors for individual trucks in the current study and linking these emissions to truck attributes such as engine model year and DPF retrofit status
- Comparing emission factors for trucks with different technology and engine model year categories observed in this study, and quantifying changes in fleet-average emission factors over time.

Background

Diesel engine exhaust is a major source of air pollution in California and has been linked to adverse health effects as well as climate change. The Statewide Drayage Rule applies to all on-road class 7 and class 8 (GVWR > 26,000 lbs) diesel-fueled vehicles

that transport cargo to and from California's ports and intermodal rail yards, regardless of the state or country of origin or visit frequency. The regulation is projected to provide significant emission reductions that will have a positive air quality impact in California – especially in and around affected ports and intermodal rail yards. Emissions measurements near California Ports are needed to assess benefits of the regulation and also identify any unintended consequences of aftertreatment control devices.

Method

Truck emissions were measured in November 2011 (378 trucks) and March 2013 (1005 trucks) near the Port of Oakland using an instrumented van that was positioned on an overpass. Exhaust/ambient air mixtures sampled above the roadway were delivered to the instrumented van via a flexible aluminum duct. In 2011 and 2013, concentrations of carbon dioxide (CO_2), nitric oxide (NO), NO_X, BC, ultrafine particle number and particle size distributions were measured at 1 Hz or faster. A video camera recorded truck license plates, which were later transcribed and matched to entries in the Air Resources Board (ARB) Drayage Truck Registry. The data provided for each truck included engine model year, engine manufacturer, and, if applicable, DPF retrofit status and installer. Fuel based emissions factors were estimated for each individual truck.

Proposal Summary

In response to Phase 1 of the drayage rule, the fraction of trucks equipped with DPF increased from 2 percent in 2009 to 99 percent in 2013, and the median engine age decreased from 11 years to 6 years. In 2013, 9 percent of the trucks sampled also had SCR systems to reduce NO_X. The following paragraphs provide a summary of major emission changes observed.

<u>Black Carbon</u>

- Average BC emission factors decreased by 76 percent ± 22 percent from 2009 to 2013. The average BC emission factors of trucks equipped with only DPFs, whether retrofit or OEM, were similar. But trucks equipped with OEM DPF plus SCR systems (2010 and newer engines) had lower BC emission factors. On average, trucks with retrofit or OEM DPFs emit 74 percent ± 30 percent less BC than trucks without DPFs, and trucks with OEM DPFs plus SCR systems emit

92 percent ± 32 percent less BC than trucks without aftertreatment. In 2013, the highest emitting 10 percent of trucks were responsible for 65 percent of total BC.

- Averaged BC emission factors for trucks with retrofit DPFs varied among manufacturers, from highest emissions to lowest as follows: Cleaire > Engine Control System (ECS) > Donaldson > and Johnson Matthey (JM) although the variability amongst certain manufacturers was significantly high which makes it difficult to conclude the aforementioned result with statistical certainty. There was no statistically significant difference in emission rates for OEM DPFs from different engine manufacturers.

Nitrogen Oxides

- The fleet-average NO_X emission factor decreased by 53 percent ± 8 percent from 2009 to 2013. The fraction of NO_2 in total NO_X rose from 3 percent in 2009 to 18 percent in 2013. In 2013, the highest 10 percent of NO_X emitters were responsible for 32 percent of total NO_X and highest 10 percent of NO_2 emitters were responsible for 37 percent of total NO_2 emissions.
- Trucks with retrofitted DPFs had the highest NO_2 emission rate, seven times higher than trucks without DPFs. The NO_2/NO_X emission ratios were greatest for newer trucks with OEM DPFs, with or without SCR. But the engines with SCR systems had much lower NO_X emissions, resulting in NO2 emission rates similar to the NO_2 emission rates of the pre-DPF era fleet measured in 2009, which demonstrates the effectiveness of SCR in mitigating the undesired increase in primary NO_2 emissions associated with use of DPFs to control exhaust PM emissions.

Particle Number and Size Distributions

- Emissions from trucks without DPFs was trimodal with peaks at 10, 20 and 80 nm with the carbonaceous peak (80 nm) dominating the emission factor weighted number distribution.
- DPFs effectively removed particles larger than 15 nm, and in contrast to some previous studies, the current data showed that use of DPFs (either retrofit or OEM) led to a decrease in total particle number and mass emission rates.

III. STAFF COMMENTS

The results from this study have been valuable to quantify emissions changes (BC and NO_X) from heavy-duty truck fleet near Port of Oakland since the introduction of the Phase 1 of the drayage rule. The authors have also provided insight into the unintended consequences such as increase in the NO_2 emissions and the NO_2/NO_X emission ratio resulting from the use of aftertreatment devices. These results are critical in evaluating the emissions reduction benefit envisioned in fleet rules and will be complemented by similar measurement studies ongoing in other parts of California.

The data also shows that the variability of emissions within individual model year increased by 2013, suggesting the degradation or failure of some installed devices. The degradation and deterioration of aftertreatment devices is an area of interest to ARB and similar studies to quantify individual truck emissions are ongoing in other parts of California (Port of Los Angeles, Cottonwood, Caldecott tunnel). The data from these studies is essential to quantify whether the benefits envisioned in the truck and bus regulation are being realized as intended. Future programs to measure heavy-duty emissions in other parts of California may also complement the heavy-duty inspection/maintenance (I+M) program currently being developed at the ARB.

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.3
DATE: October 3, 2014
CONTRACT NO.: 10-325
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Cool California Carbon Challenge: A Pilot Intra-Inter-Community Carbon Footprint Reduction Competition
CONTRACTOR:	University of California, Berkeley
PRINCIPAL INVESTIGATOR:	Daniel M. Kammen, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$300,004
CONTRACT TERM:	42 months

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

I. SUMMARY

Achieving California's 2020 and 2050 climate goals will require voluntary reductions of residential greenhouse gas (GHG) emissions, as recently noted in the AB 32 Scoping Plan update. However, motivating behavioral change can be difficult: improved access to information does not generally suffice to motivate individuals and communities to adopt energy-saving behaviors, even when these behaviors are in the individuals' economic best interests. Competitions and community-based social marketing (including strategies such as goal-setting, modeling of normative behaviors, feedback, rewards, and tailored carbon footprint reduction recommendations) have demonstrated some success in motivating environmentally friendly behavior. This project conducted and evaluated a pilot carbon footprint reduction competition over a 13-month period in eight California communities, and enrolled 2,667 households. Over 900 participants manually entered more than 10,000 monthly electricity, natural gas and motor vehicle readings in the online software, far exceeding the level of participation anticipated at the outset of the program. Households who joined earlier in the program used less electricity than similar households that joined the program at a later date. The results

suggest that inter-city competitions can be an effective tool to support California's efforts to curb residential GHG emissions.

II. TECHNICAL SUMMARY

Objective

The goal of this project was to develop and implement a pilot competition, and to evaluate the competition both quantitatively in terms of emissions and reductions tracked through online software, and qualitatively through surveys of participants and interviews with city program managers.

Background

A number of recent studies have concluded that large scale adoption of energy efficient and low carbon technologies will be required for California to meet its 80 percent GHG reduction target (Executive Order S-3-05). These studies further show that even if low carbon technologies can be scaled up to near technical potential, additional savings will be required from conservation, or else entirely new technologies will need to be developed, likely at considerable cost. Studies of residential energy consumption also show that behavioral factors can account for substantial variability in household carbon footprints, despite similar demographics, locations, and household sizes. And, unlike changes in technology and infrastructure, which require heavy investments and long lead times, behavior change programs can offer quick and potentially low-cost solutions.

Efforts to encourage pro-environmental behaviors have been largely limited to small-scale projects that target actions for specific populations. One approach, providing comparative feedback via home energy reports, has reached large scales; however, savings have been modest, typically between 1-2 percent. Low-cost, highly scalable intervention models that achieve deeper savings for a large, diverse population are needed to ramp up greenhouse gas reductions. Inter-city energy and greenhouse gas reduction competitions have only recently been tried (e.g., Mass Saves Challenge, the Kansas Energy Challenge). Previous programs have not been rigorously evaluated and little is known about why programs may or may not be successful. This study provides one of the first opportunities to evaluate a statewide inter-city competition.

Project Summary

This study tracked self-reported monthly natural gas and electricity consumption by approximately 900 total participants who recorded their monthly usage an average of five months per household. Participants were asked to complete a research survey, including questions on their values, attitudes, motivations, commitment to sustainable lifestyles, and demographic characteristics. In order to understand the effectiveness of the program to engage different population segments, the researchers compared points earned by households to responses from the research survey. Participants earned points earned for: 1) having lower energy consumption and motor vehicle usage than similar California households; and 2) lowering energy usage and motor vehicle usage over time, and 3) taking simple, one-time actions.

Any California city interested in the program was encouraged to apply and participate. The first six cities that applied received $1,000 in seed money. Ten cities completed the application process by the required date; however, two cities, Gonzales and Santa Cruz, dropped out prior to the start of the competition due to staffing constraints, leaving eight cities in the pilot competition:

- Chula Vista
- Citrus Heights
- Davis
- Pittsburg
- Pleasanton
- San Jose
- Sacramento
- Tracy

These cities reflected a demographically diverse population with a range of population sizes as well as different levels of capacity and experience with community climate action. All cities had recently completed climate action plans that called for some level of engagement with residents. In many cases the Challenge was the city's first engagement with residents on this issue.

The Challenge started on April 1, 2012 and ran through May 30, 2013. April 2012 was a "warm up month." The "Qualifying Round," ran from May 1 through July 31, 2012, and was designed to select the most dedicated cites to compete to become the "Coolest California City." At the end of each month of the Qualifying Round the city with

the most points was deemed a “Finalist” and awarded $10,000 in “seed money” to support local implementation of the program. The City of Davis became the first finalist at the end of May, followed by the City of Sacramento at the end of June. The remaining cities competed for the last finalist spot during the month of July. Tracy and Chula Vista tied for third place and agreed to share the prize money ($5,000 each). The “Finalists Round” ran from August 1, 2012 through April 30, 2013, and cities were given until May 30th to enter energy bills and vehicle odometer readings for the month of April. At the end of the one-year pilot, the City of Davis had earned the most points and was officially declared the “Coolest California City” at an awards ceremony at the California Air Resources Board meeting in Sacramento. The City of Chula Vista came in a close second place and the City of Tracy was third place.

To encourage participants to actively engage in the competition, the Challenge employed a number of strategies common to community-based social marketing and behavior-based energy reduction programs. Strategies included: 1) feedback to participants to let them know how well they were doing; 2) normative messaging to inform them how others like them behave and what behaviors are expected by peers; 3) social diffusion, tapping into existing social networks in communities; 4) local leadership and capacity building; 5) commitments and goal setting, such as competition deadlines and the program goal of reducing 500,000 pounds of CO_2; 6) incentives, including recognition of winners, and raffles through the online software; and 7) persuasive messaging, largely in the form of photos, stories, and other peer-to-peer learning shared through social media and other participant interactions. Participants tracking electricity saved an average of 14 percent compared to a quasi-control group, while no discernible savings were measured for natural gas.

All participants were asked to voluntarily complete a research survey during and after the competition. Three hundred thirty-four participants successfully completed the online survey. Six months following the end of the program participants were asked to log into the Challenge software and take a second survey that included additional questions evaluating their experience in the program. Sixty-three participants completed the second survey. Challenge participants were well represented across income brackets, but were primarily highly educated, politically liberal and middle-aged, with strong

pre-existing pro-environmental attitudes and practices. Young people were much less likely enroll and to actively participate and earn points in the program, suggesting that future program interventions would need to be much more highly tailored to their needs in order to earn their engagement. While conservatives and “practical spenders” were less likely to enroll in the program, those who did performed well compared to more liberal counterparts. Education was an important factor; participants with advanced degrees earned two to three times more points than participants without a college degree. Considerable effort would be needed to actively engage populations with less formal education. The most active participants were “leading achievers” and “practical spenders,” with “striving believers” straggling behind on points per household.

Households reported very altruistic and intrinsic motivations for participating in the program, with helping their community, making an environmental statement and supporting organizations they care about topping the list of motivations. Their values were also very much aligned with protecting the environment and improving their communities, regardless of political orientation or demographic characteristics. Although many participants already led low carbon lifestyles, they demonstrated strong capacity to make further reductions during the program. Participants were most actively engaged in the program during the most intensive months of competition (summer 2012 and spring 2013), suggesting that competition is a useful strategy to catalyze participation and engagement.

Several months after the end of the program, city program managers were interviewed about their city’s experience participating in the program. The interview included questions on their city’s motivations for joining the program, the resources they had at their disposal to run the program, their evaluation of each of the main program activities, their opinion on the outcome and results, and their recommendation for future programs. Six city program managers completed the interviews. City program managers stressed that future programs should seek to increase motivation for all cities, even those not directly contending for top honors, and that programs like this should be designed to meet a wide range of needs from communities with different levels of capacity and diverse populations. They also noted that future programs should target youth and young adults more specifically, and that additional funding or incentives

would be valuable. They also pointed out that programs should experimentally test different messages and intervention strategies to see which are most effective locally.

III. STAFF COMMENTS

ARB's Research Division staff, the California Energy Commission, the California Public Utilities Commission, ICLEI – Local Governments for Sustainability, the Institute for Local Government, Pacific Gas & Electric Company, Southern California Edison, and the California Center for Sustainable Energy reviewed and provided comments on this report. Overall, reviewers agreed that this project was an important contribution to the emerging area of behavioral research on energy use, particularly the use of competitions, and noted that these types of programs will be increasingly important in achieving California's climate goals. Several reviewers noted that the relatively small number of participants who regularly entered energy and travel data, and the lack of a comparison group, were limitations that should be addressed in future research.

The researchers met their goal of implementing and evaluating a pilot, household carbon footprint reduction competition. The researchers developed recommendations for improving the effectiveness of programs like this one for engaging a wider audience and for keeping cities that are not the top performers more engaged throughout the competition. RD staff hopes this research will support the development of more effective behavior-based programs in California, delivered through energy utilities or non-profit organizations. ARB continued this program (with some modifications informed by this research project) beyond the initial pilot, in partnership with the California Center for Sustainable Energy, which is implementing the Public Utilities Commission's "Energy Upgrade California" program.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee approve this draft final report, subject to any changes and additions specified by the Committee.

DISCUSSION OF A DRAFT FINAL REPORT
ITEM NO.: III.4
DATE: October 3, 2014
CONTRACT NO.: 11-323
Link to Report

STAFF EVALUATION OF A DRAFT FINAL REPORT

TITLE:	Quantifying the Comprehensive Greenhouse Gas Co-Benefits of Green Buildings
CONTRACTOR:	University of California, Berkeley
PRINCIPAL INVESTIGATORS:	Ed Arens, Ph.D. Louise Mozingo, Ph.D.
CONTRACT TYPE:	Interagency Agreement
TOTAL AMOUNT:	$180,000
CONTRACT TERM:	30 months

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

I. SUMMARY

Buildings represent the second largest source of California's greenhouse gas (GHG) emissions when evaluating energy usage alone. Commercial buildings generated 10.8 percent of statewide GHG emissions in 2008. As California moves towards better quantifying greenhouse gas emissions reductions associated with energy efficiency improvements in buildings, research was needed to fully account for the GHG emissions reductions associated with related improvements in the water, waste, and transportation components of building projects. The objective of this research was to develop a database of certified commercial green buildings in California that included performance metrics to measure GHG emission reduction co-benefits due to water savings, waste reduction, and minimized transportation impacts. This information will be useful in quantifying additional GHG emission reductions beyond energy savings in commercial buildings to assist with meeting long-term climate goals.

II. TECHNICAL SUMMARY

Objective

The main objective of this research was to create a database of certified green buildings in California to measure the comprehensive GHG co-benefits of building-related water savings, waste reduction, and minimized transportation impacts. Using key performance metrics that relate to these sectors, the research team compiled a dataset of certified green buildings to compare the GHG emission reduction potential outlined in the literature with the actual measured GHG savings of these certified green buildings. This research will assist with quantification of GHG emission reductions from new construction, maintenance, and operation of commercial green buildings.

Background

Green buildings are not just energy efficient buildings; they are designed, built, operated and maintained to reduce water consumption, solid waste, and transportation-related impacts. These ancillary greenhouse gas benefits are not typically reflected in the current GHG emission reductions estimates for the building sector. As part of this research project, investigators developed a database of California green buildings. The database can be used to quantify the comprehensive GHG co-benefits of the water, waste, and transportation related components of green buildings. The results of this study fill a critical research gap to quantify additional non-energy GHG emission reductions of California green buildings.

Proposal Summary

The research team gathered data on California buildings certified under two green building rating systems, Leadership in Energy and Environmental Design for new construction (LEED-NC) and LEED for existing building maintenance and operations (LEED-EBOM). They collected data on the points each building achieved through the rating system to identify specific measures that were later evaluated.

The research team compiled three types of data to estimate GHG emission reductions. They gathered actual values for water consumption, waste generation, and vehicle miles traveled to calculate measured GHG emission reductions. They obtained data on predicted values to forecast potential GHG emission reductions. Lastly, they collected

baseline values for typical water usage, waste generated, and transportation impacts in commercial buildings. All of the data gathered was compiled into a series of coordinated datasets. Additional information on building characteristics, supporting data and equations were compiled into the database.

Using the data collected in the first three tasks, the research team ran analyses to calculate the GHG co-benefits of LEED-certified commercial buildings. Comparing predicted and measured values revealed whether green buildings perform as projected. Researchers compared the measured values with the baseline values to gain a better understanding of how green buildings compare to standard buildings.

The research team identified opportunities to expand existing building energy use forecasts and surveys to include non-energy features such that they capture the comprehensive range of energy and greenhouse emission benefits associated with all building related improvements.

This research has found that pursuing LEED-EBOM green building certification in commercial office buildings is resulting in important greenhouse gas reductions due to improvements in transportation, water use, and waste generation when compared to traditional buildings. On average, the LEED-EBOM green buildings analyzed in this research produced 63 percent less GHGs due to water consumption than baseline buildings; 48 percent less GHGs due to solid waste management; and 5 percent less due to on-site transportation strategies. Applied to an average-sized California office building (13,000 ft^2), these GHG reductions would total 10.59 $MTCO_2e$/year relative to a same-sized traditional office building.

These findings suggest there is significant potential to reduce greenhouse gas emissions through non-energy green building strategies, and future updates to the state's mandatory green building code should consider advancing these strategies. In addition, the research found that while the transportation sector is the most difficult to affect relative to other sectors, they offer significant potential in absolute terms because of the significant GHG-intensity of travel. Given this significant potential, it may be

beneficial for state building codes to begin to consider inclusion on on-site transportation strategies.

III. STAFF COMMENTS

This report was reviewed by staff in ARB's Research Division and the Air Quality and Planning Section; the California Department of Transportation; the Integrated Waste Management Board; the Department of Water Resources; the Department of General Services; the U.S. Green Building Council; and StopWaste.org. Select comments received by reviewers include a clearer discussion of how the resource savings and GHG reductions that were found could be extrapolated to the state's entire commercial building stock; additional clarification regarding some aspects of the methodology and associated assumptions; and correction of select calculation errors. Staff communicated these comments to the research team, which provided an updated draft final report incorporating most of the suggested changes. Staff has no additional concerns or issues regarding the draft final report at this time.

The findings of this report have particularly important implications for the state's efforts to address climate change through green building. The research findings show that green building certification provides unique reduction value above and beyond energy-efficiency related efforts. These findings suggest that as the state advances zero-net-energy building policy, efforts to improve the non-energy impacts of building need to be continually advanced as well. In particular, these findings support consideration of building upon the state's zero-net energy building policies to move toward zero-carbon building, which are buildings that would utilize high performance design solutions, generate renewable energy on-site, and employ other techniques to eliminate or offset the GHG emissions associated with the energy, as well as the water, waste, and transportation impacts of a building.

In addition, this research demonstrates the sizeable contribution transportation to/from buildings make to a building's carbon footprint. To date, with the exception of one known regional ordinance, on-site transportation demand management strategies, such as bicycle facilities, commuter benefits, carpool/vanpool programs etc., have largely been left to voluntary efforts. There may be an opportunity to utilize California's Green

Building Code as a mechanism through which on-site transportation demand strategies can be more widely implemented.

IV. STAFF RECOMMENDATION

Staff recommends the Research Screening Committee approve this draft final report, subject to any changes and additions specified by the Committee.