

**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**

**August 25, 2017  
9:00 a.m.**

**ADVANCE AGENDA**

I. Approval of Minutes of Previous Meeting:

March 30, 2017

II. Discussion of Requests for Proposals (RFP):

1. "Development of Real-time, Portable Measurement Method for Detecting, Screening, and Quantifying Airborne Toxic Metal Concentrations," \$400,000, RFP No. 17RD022
2. "Measuring Emissions from the On-Road Vehicle Fleet in West Los Angeles," \$40,000, RFP No. 17RD015
3. "Identify Outlier LDV Makes and Models of Light-Duty Vehicles Using RSD Data," \$75,000, RFP No. 17RD014

III. Discussion of Contract Multiple Award Schedule (RFO) Solicitations:

1. "Policy, Planning, and Program Frameworks for Zero-Net Carbon Communities," \$250,000, RFO No. 17RD020
2. "Brake and Tire Wear Emissions," \$350,000, RFO No. 17RD016

IV. Discussion of New Research Projects:

1. "A Tool to Prioritize Sources for Reducing High PM<sub>2.5</sub> Exposures in Environmental Justice Communities in California," University of Texas at Austin, \$180,000, Proposal No. 2805-287

California ambient PM<sub>2.5</sub> concentrations have decreased by up to 30 percent in the past two decades; however, disadvantaged or environmental justice (EJ) communities

are still exposed to higher levels of PM<sub>2.5</sub> than non-EJ communities. It is critical to identify sources contributing to higher PM<sub>2.5</sub> levels in EJ communities and prioritize them for emission reduction. This proposal aims to develop a screening tool to identify and prioritize sources contributing to higher levels of PM<sub>2.5</sub> observed in EJ communities in California. This project will generate a comprehensive database of intake fraction (if, the fraction of an air pollutant emitted by a source that is inhaled by the population), intake, and a set of metrics indicating PM<sub>2.5</sub> exposure disparity for different disadvantaged communities and vulnerable populations for primary and secondary PM<sub>2.5</sub> in California. This project will also evaluate the relative importance of emission sources in terms of their impacts on exposure and exposure disparity by source location and source category, and assemble a list of sources that have greater-than-average impacts on PM<sub>2.5</sub> concentrations in EJ communities in California. The results of this project will help inform strategies to prioritize emission sources for control to reduce the levels of PM<sub>2.5</sub> in EJ communities and minimize exposure disparities in California.

2. "Combined Exposure to UFPM and O<sub>3</sub>: Characterization of Particulate Deposition, Pulmonary Oxidant Stress and Myocardial Injury," University of California, Davis, \$196,806, Proposal No. 2806-287

Epidemiologic research has suggested a statistical correlation between exposure to PM and ozone (O<sub>3</sub>), and adverse health effects. Findings obtained in the previously recent ARB funded investigation, "Co-Exposure to PM and O<sub>3</sub>: Pulmonary C Fiber Platelet Activation in Decreased HRV," demonstrated that exposure to a combination of ultrafine particulate matter (UFPM) and ozone increases the biological potency of exposure, resulting in exaggerated pulmonary and cardiac patho-physiological responses compared to single pollutant exposure in mature normal and spontaneously hypertensive adult rats. This was the first study to provide direct evidence of air pollution exposure-induced myocardial injury in an animal model. The currently proposed study will conduct immunostochemical analysis, immunohistopathological analysis, and UFPM mapping in previously collected pulmonary and myocardial tissue samples from the aforementioned study and is expected to elucidate the mechanistic basis of the increased biological potency resulting from combined acute exposure to UFPM and O<sub>3</sub> in rats with and without cardiovascular disease (CVD). This work is critical for improved scientific

understanding of the adverse health effects of combined-pollutant exposure and is expected to provide additional guidance and rationale for future regulatory actions regarding multipollutant exposures.

3. "Characterization of Air Toxics and Greenhouse Gas Emission Sources, and Their Impacts on Community-Scale Air Quality Levels in Disadvantaged Communities," FluxSense, \$225,000, Proposal No. 2807-287

Methane is an important short-lived climate pollutant, and contributes roughly nine percent to the statewide greenhouse gas (GHG) emissions. California has passed several recent climate legislations, including Assembly Bills (AB) 1383 (Lara, 2015-16) and AB 1496 (Thurmond, 2015-16), which require ARB to use the best available scientific and technical methods to monitor and measure high emission methane hotspots within the State. This information is used to update relevant programs and policies, and to implement a climate mitigation program to reduce statewide methane emissions by 40 percent below the 2013 levels. Additionally, several scientific studies have suggested that national and statewide GHG emissions inventories for methane sources are underestimated, but there is limited updated source-specific emission rate data in California that can be used to update the statewide inventories. Furthermore, certain industrial emissions sources, such as oil and gas facilities, are known to co-emit air toxic emissions that have adverse health effects, and their impacts may be more pronounced in neighboring communities when compared to regional air quality monitoring stations. Therefore, it is important to understand these emissions, and conduct enhanced community-scale monitoring for air toxics in near-source communities, many of which may be disadvantaged.

The objectives of this research study are to characterize air toxics and GHG emission behavior from a variety of complex emission sources, and to study the impact of these sources on air quality levels in disadvantaged communities. The project will utilize a state-of-the-art research grade mobile monitoring laboratory equipped with advanced monitoring instruments for ground-level air toxics measurements, as well as ground based flux measurements of GHGs and air toxics. The source-level emission measurements will enable ARB to improve and update current emission inventories of complex emission sources (including large point sources, distributed emission sources, area sources), as well as help quantify the emission fluxes from methane

super-emitters identified by parallel research efforts. The community-scale measurement effort will provide the ability to conduct community-scale air toxics measurements in real-time, with information on air pollution hotspots in various disadvantaged communities and useful screening information to identify potential sources for prioritizing air pollution mitigation efforts.

4. "Effects of Brake and Tire Wear on Particulate Matter Composition, Reactive Oxygen Species, Placental Development and Birth Outcomes in Los Angeles," University of California, Los Angeles, \$458,814, Proposal No. 2808-287

Ambient PM is known to be associated with an array of adverse health effects, although little is known of the components or sources of PM that are most relevant to these health impacts. In addition, although PM pollution is still a concern, through regulations and advanced technology there have been reductions of PM air pollution, particularly from motor vehicle exhaust emissions. Therefore, the relative proportion of non-exhaust sources, such as from tire and brake wear, will increase in near roadway PM as these sources have not been a focus of control strategies.

The proposed study will measure PM metal constituents, and ROS associated with PM from brake and tire wear, and will generate predictive models to link with health effects such as birth outcomes and placental abnormalities. Study results will potentially fill gaps in knowledge about the mechanisms and potential exposure to specific components behind the relationship between traffic-related air pollution and adverse birth outcomes in California. Scientific evidence from this study will increase our understanding of the spatial distribution of PM from brake and tire wear and its health impacts and can provide information to help ARB protect public health through control measures.

5. "Geofencing as a Strategy to Lower Emissions in Disadvantaged Communities," University of California, Riverside, \$300,224, Proposal No. 2809-287

Previous in-house ARB research comparing the trends in traffic-related pollutant concentrations in high and low socioeconomic status communities has shown that while ambient fine particles (PM<sub>2.5</sub>) concentrations are decreasing everywhere, higher concentrations are still found in the most disadvantaged communities (DACs). Geofencing is a promising new strategy to reduce such exposures. Geofencing allows

a user to define virtual spatial boundaries on top of a real-world view of a specific geographical area within which a pollution emitter, such as HDVs, could be triggered to employ methods to reduce emission. This project aims to identify and evaluate geofencing strategies in the heavy-duty sector that could lower emissions in DACs or other areas of poor air quality, either all the time or during specific time periods. The researchers will model emission reductions associated with the implementation of geofencing strategies in the selected study areas, relative to a baseline scenario. The results from this research will provide important information that could be used to inform the development of geofencing technologies, as well as the development of incentive or regulatory policies by ARB, that reduce pollutant emissions in DACs.

6. "Emissions Impact of Connected and Automated Vehicle Deployment in California," University of California, Davis, \$220,000, Proposal No. 2810-287

The transportation sector is undergoing a rapid transformation towards connected and automated vehicles (CAVs). This transformation could result in a variety of outcomes, including several that would result in serious negative environmental and social impacts, such as the possibility that CAVs will spur an increase in light-duty vehicle miles traveled (VMT) and more dispersed land use development due to falling travel costs, zero-occupancy or dead-heading abilities for CAVs, and the ability for CAV occupants to engage in other activities while they travel. These outcomes would make it more difficult for California to meet its air quality and GHG emission goals. Thus, it is important for California agencies and policymakers to identify and understand policies that will help the state avoid and/or mitigate these potential outcomes. To inform proactive policy development, this project will develop realistic scenarios that reflect the many possible aspects of future CAV penetration, and will quantify the associated energy usage, VMT, and GHG and criteria pollutant emissions outcomes. This project will inform the next generation of Advanced Clean Cars regulations and policies related to Senate Bill 375, among others.

7. "Activity Data of Off-Road Engines in Construction," University of California, Riverside, \$200,000, Proposal No. 2811-287

The relative contribution of off-road construction equipment to the NO<sub>x</sub> emissions in the State is expected to increase as emissions continue to decline from on-road HDVs. However, the current understanding of the emissions from off-road sources is

considerably more limited compared to on-road mobile sources. The activity estimates being used in the current version of the OFFROAD model are based on survey data from before 2010, with much of that data not being specific to California fleets. Additionally, given the wide range of off-road engine applications, average engine “load factors” can be different than certification test cycle load factors. Collecting realistic activity profiles of off-road sources are critical for developing accurate emission inventories and realistic certification cycles. This proposal addresses the importance of collecting new activity data to reflect the changes in the construction sector since 2010 and the latest generation of emission control systems being used in off-road applications. The current study will expand on UCR and ARB studies by focusing on the activity data collection that will cover a comprehensive array of equipment types and engine power ratings for construction equipment, and later extending the collection to agricultural equipment. For this study, activity measurements will be made from 10 individual pieces of equipment representing a range of engine sizes, from each of 10 different equipment categories, for a total of 100 pieces of equipment. The data will be analyzed to provide summary statistics, including number of engine starts per day and distribution of soak times, as well as statistics and distributions of durations, load factors, and exhaust temperatures for each vocational use. The data will also be evaluated to assess the representativeness of existing engine certification cycles and to assess the suitability of effective NO<sub>x</sub> control by SCR for different equipment types.

8. “Spatial Variation of Vertical Ozone Distribution Over California,” National Aeronautics and Space Administration, \$65,548, Proposal No. 2812-287

Because health effects research has consistently led to more stringent ambient air quality standards for ozone (O<sub>3</sub>), California must continue to achieve reductions in O<sub>3</sub> precursor emissions. However, background O<sub>3</sub> from other sources outside the State’s control can also affect California’s air quality. Due to increasing baseline O<sub>3</sub>, the atmospheric transport mechanisms have the potential to make attainment of the stringent O<sub>3</sub> National Ambient Air Quality Standards (NAAQS) increasingly more difficult in regions like the San Joaquin Valley (SJV). To better understand the ground-level O<sub>3</sub> contributions from the transport and the atmospheric processes in the SJV, the California Baseline Ozone Transport Study (CABOTS) produced a

three-month dataset of aloft O<sub>3</sub> data collected with ozonesondes and an O<sub>3</sub> lidar during May - August 2016. The National Aeronautics and Space Administration (NASA) Alpha Jet Atmospheric eXperiment (AJAX) group, an unfunded collaborator, conducted eight flights designed to investigate the incoming air, the variability of free-tropospheric O<sub>3</sub>, and the atmospheric transport of O<sub>3</sub> across the State during the CABOTS field campaign. AJAX flights linked ozonesonde launches at the coast to lidar measurements in Visalia. This project will finalize and complete the analysis of the data collected by the NASA AJAX group during CABOTS, which will provide additional insight into baseline O<sub>3</sub> transport mechanisms from the Pacific and into the SJV. The results will help ARB determine if and how atmospheric O<sub>3</sub> transport impacts ground-level O<sub>3</sub>, especially on days when the O<sub>3</sub> concentrations exceed the NAAQS in the SJV. The information can also help evaluate and improve the representation of the horizontal transport and downward mixing processes of O<sub>3</sub> aloft in the regional air quality and meteorological models needed for the development of the State Implementation Plans.

9. "Long-Term Characterization of Fine PM Chemical Composition in the San Joaquin Valley," University of California, Davis, \$320,000, Proposal No. 2813-287

PM pollution in the San Joaquin Valley (SJV) in wintertime remains the worst in California, frequently exceeding the 24-hour National Ambient Air Quality Standard (NAAQS). In addition, summertime PM<sub>2.5</sub> concentrations are also sufficiently large enough to frequently exceed the annual PM<sub>2.5</sub> NAAQS. A process-level understanding of PM<sub>2.5</sub> formation in the SJV has been limited, however, by a lack of chemically resolved measurements of PM<sub>2.5</sub> concentrations needed to assess the long-term trends, seasonal variabilities, and diurnal differences in the formation processes. This project will address this need by collecting two years of continuous PM<sub>2.5</sub> chemical speciation data at a site in the SJV using a Time-Of-Flight Aerosol Chemical Speciation Monitor (TOF-ACSM). Hourly data will be processed to yield mass loadings of ammonium, sulfate, chloride, nitrate, and organic species. Analyses of this data will produce an unprecedented level of detail into diurnal variability as a function of seasonal changes, weekend/weekday differences, residential burning-allowed and burning-not-allowed periods, and local meteorological variation (temperature, RH, wind direction and speed). Results are expected to provide insights

into the sources and key atmospheric processes that drive PM<sub>2.5</sub> formation in the valley during different seasons and supply a scientific basis for the development of optimal PM<sub>2.5</sub> ammonium nitrate and organic aerosol mitigation policies.

V. Discussion of Proposed Contract Augmentations:

1. "Advanced Plug-In Electric Vehicle Travel and Charging Behavior," University of California, Davis, \$75,000, Contract No. 12-319

This project was originally approved by the RSC in 2012 to advance ARB's research related to advanced technology vehicles. A contract augmentation is requested so that the contractor can perform additional analyses which are outside of the scope of the original contract. This project's overall objective is to collect and analyze in-use vehicle data from a variety of plug-in electric vehicle (PEV) types in a household context to improve estimates of vehicle emissions and provide insights into their real-world benefits. PEVs constitute a growing share of new light-duty vehicle sales, but their environmental benefits vary depending on consumer usage and charging behavior. Recently it was found that a subset of PEVs called "blended" plug-in hybrid electric vehicles (PHEVs) had high cold-start emissions under high power demand conditions, (such as on ramp acceleration or steep hill climbs), and that these PHEV engine start events could produce higher emissions than traditional internal combustion engine (ICE) cold starts. Data already collected under contract 12-319 offer a unique opportunity to assess the emissions impact of these blended PHEV high power engine starts. The additional funds will be used to mine activity data to identify conditions leading to these high-power starts and estimate their emissions impacts. The results of this project will be used to update emission inventories as well as inform future policy related to the Advanced Clean Car regulation.

2. "Characterizing the Climate Impacts of Brown Carbon," University of California, San Diego, \$50,000, Contract No. 13-330

A contract augmentation is requested to enhance assessment of the net contribution of brown carbon (BrC) in California and supplement the evaluation of its global impacts. BrC refers to organic compounds contained in airborne particles that absorb incoming shortwave solar radiation leading to heating of the atmosphere. Measurements and model calculations indicate that BrC has the potential to be a



strong global warming component and to have negative consequences for public health through its contributions to PM<sub>2.5</sub>. The current project has been successful to reduce the uncertainty associated with the global warming potential of BrC by measuring the optical properties in-situ under both summer and winter conditions in California. While remaining uncertainty stems primarily from differences in model emissions and scales, the expanded scope of work in this proposal addresses both of these sources of remaining uncertainty, improving the model and observation comparisons. The supplemental funding would ensure that all of these new inputs can be used to the maximum extent. The results of this study are expected to improve ARB's understanding of the fundamental processes that dominate BrC formation and its evolution in the atmosphere and help ARB to determine the climate benefit of the ongoing mitigation of BrC emission sources in California.

#### VI. Discussion of Draft Final Reports:

1. "Protocol Development for Vehicle Emission Toxicity Testing for Particulate Matter," University of California, Davis, \$100,000, Contract No. 14-305

Toxicological testing of particulate samples is an integral aspect of evaluating possible health effects associated with PM from new engine technology studies and source specific ambient PM. However, there are a multitude of possible standard operating procedures (SOPs) for sample preparation, each with inherent advantages and disadvantages. This is not surprising since all of these procedures require physical and chemical manipulation of the PM sample during isolation which can affect its inherent toxicological properties. The main objective of this study was to systematically investigate these different SOPs and evaluate which procedures can retain of the most toxicologically relevant chemical components of the sample for various toxicological assays while producing the fewest toxicological artifacts. To study the effect of sample preparation on the toxicity of diesel exhaust particles (DEP), six different sample preparation techniques were chosen for toxicological screening via a multi-point standard assay panel. The DEP samples studied include a NIST standard and filter samples collected from the exhaust stream of a dilution tunnel during a chassis dynamometer study. These samples were prepared using two whole particle and four selective (i.e. PM fractionation) extraction techniques. All sample extracts were toxicologically screened for ROS production via the acellular

dithiothreitol (DTT) assay, cellular inflammation via the cyclooxygenase-2 and interleukin-8 expression measurements, PAH response via cytochrome P450 1A1 expression, and mutagenicity via the microsuspension Salmonella/microsome assay. Results demonstrated that: 1) selective extraction techniques consistently tend to enhance the effect of the more active DEP components by removing the less reactive matrix components that are included in whole particle techniques; 2) nonpolar compounds elicit the greatest responses across all assays except for ROS production, which is largest for the more polar DEP components; 3) strong evidence exists for composite interference or toxicological matrix effects, where the sum of responses to individual components is greater than the response to the composite of those components; and 4) although different sample preparation techniques appear to be equally repeatable across different assays, the techniques eliciting the most robust response are assay-specific and include cases where multiple techniques are equally effective. The regulatory and policy implications are the establishment of recommendations and guidelines for future ARB funded projects which require *in vitro* toxicological analysis of filter based sample media.

2. "Co-Exposure to PM and O<sub>3</sub>: Pulmonary C Fiber Platelet Activation in Decreased HRV," University of California, Davis, \$600,782, Contract No. 13-311

People are routinely exposed to ambient air that contains a complex mixture of air pollutants. Particulate matter (PM) and ozone (O<sub>3</sub>) appear to be responsible for the majority of serious health effects related to air pollution exposure, although little is known about whether or not they have interactive or synergistic effects on health endpoints. Exposure to PM has been significantly associated with adverse cardiovascular effects in a number of studies, and recently published results have suggested that ozone exposure, well-known to induce respiratory effects, may also have cardiovascular effects. The main objective of this study was to measure and compare changes in pulmonary and cardiovascular physiological and pathological endpoints in laboratory animals acutely exposed to a combination of O<sub>3</sub> and PM with effects of these air pollutants alone. Normal and spontaneously hypertensive (SH) rats with implanted telemetry units that recorded the electrocardiogram and breathing pattern were exposed for six hours to filtered air, and flame generated ultrafine particulate matter (UFPM) and O<sub>3</sub>, alone and in combination. At the end of the acute

exposure period, animals were euthanized, and both pulmonary and myocardial tissues were isolated for additional analysis. The results showed that both strains of rats exposed to O<sub>3</sub> + UFPM had significant differences in the severity of ventricular entropy, severity of arrhythmias and ventricular pre-contractions as well as total number of atrial-ventricular block events when compared to filtered air exposed animals. In addition, the S rats had changes in heart rate regulation and arrhythmias associated with acute myocardial cellular necrosis, hypercontractility, and focal myocardial organized necrosis. The results from this study will advance the understanding of the biological mechanisms mediating the cardiovascular and pulmonary effects of multi-pollutant exposures, and how different mechanistic pathways converge to induce adverse health effects. This knowledge will contribute to development of health protective ambient air quality standards, and may also contribute to development of new efficient emissions reduction approaches that target more than one air pollutant simultaneously, as well as those which consider the effects of acute exposures.

3. "Cardiovascular Effects of Multipollutant Exposure: Mechanisms and Interactions," University of California, Irvine, \$740,425, Contract No. 13-309

Epidemiological studies have associated higher levels of heart-related hospitalizations and deaths with exposures to elevated levels of fine particle (PM<sub>2.5</sub>). Ozone (O<sub>3</sub>) has been implicated in respiratory health effects, but there is also evidence of O<sub>3</sub>-related deaths from heart-related illnesses. Biologically, inhalation of either of these pollutants can result in formation of ROS, oxidative stress, and inflammation, which are involved in the formation of atherosclerotic plaques, increases in blood pressure, changes in heart rate variability and increased frequencies of abnormal heart beats. Therefore, the present study investigated whether chronic exposure to these two pollutants acting in concert can produce worse outcomes than either acting alone. One of the main findings of the study was that, counter to expectations, effects of concurrent chronic exposures to CAPs + O<sub>3</sub> were not worse than the effects of exposures to the individual pollutants. A second important finding was that CAPs generated in ambient air during periods of high photochemical activity (i.e. summer) may be more toxic than CAPs generated in the lower photochemical period. Finally, it was determined that the effects of long-term exposure to CAPs with the organic constituents removed (deCAPs), when added to

O<sub>3</sub>, did not differ from the effects of O<sub>3</sub> alone. These results highlight the importance of understanding the complexity of interactions between air pollutants and their health impacts, which should be considered in setting regulations and ambient air quality standards to protect the health of all Californians.

4. "The Development of Lifecycle Data for Hydrogen Fuel Production and Delivery," University of California, Davis, \$250,000, Contract No. 14-318

The Low Carbon Fuel Standard (LCFS) currently includes several pathways for hydrogen (H<sub>2</sub>) fuels. This project was developed to provide LCFS staff with additional pathways for the production of renewable hydrogen and an evaluation of renewable hydrogen production technologies anticipated to be available in the short, mid and long term timeframes. The conversion technologies addressed in the study included thermal processes, electrolytic processes, photolytic processes, and biochemical processes. A lifecycle analysis using the CA-GREET Tier 2 model was performed on a subset of the production technologies for both centralized and distributed pathways. An economic analysis using the H<sub>2</sub>A model was performed on these pathways. The resulting GHG emissions (gCO<sub>2</sub>e/MJ H<sub>2</sub>) and hydrogen cost (\$/.kg) are reported. Sensitivity analyses were performed for both cost and emissions. A review of the potential to inject hydrogen into natural gas pipelines for distribution was also performed. The review considered issues such as safety, hydrogen leakage, embrittlement of pipelines, general risk, and extraction of hydrogen. The potential hydrogen demand from non-transportation fuel cell markets was estimated over a ten year timeframe. Specific markets considered were material handlers (forklifts), transport refrigeration units (TRUs), airport ground support equipment, and telecommunications backup power.

5. "Improving DNDC Modeling Capability to Quantify Mitigation Potential of Nitrous Oxide from California Agricultural Soils," University of New Hampshire, \$199,271, Contract No. 14-306

Nitrous oxide (N<sub>2</sub>O) is a potent GHG, comprising about 3 percent of California's GHG inventory in 2015. Emissions from agricultural soils represent the main source of N<sub>2</sub>O in California, contributing more than 5.8 metric million ton of CO<sub>2</sub> equivalent (MMT CO<sub>2</sub>E) or 50 percent of total N<sub>2</sub>O emissions. Emissions of N<sub>2</sub>O from agricultural soils are closely related to soil nitrogen (N) content, but can be affected significantly by environmental factors such as soil organic carbon content and soil water content.

Therefore, it is possible to mitigate N<sub>2</sub>O emissions by best management practices that alter environmental conditions. Numerous studies have demonstrated that N<sub>2</sub>O emissions from agricultural soils can be reduced effectively by various management practices. However, to assess mitigation potentials in a quantitative manner under diverse cropping systems and farming management practices, a process-based modeling tool would be required that is capable of simulating environmental impacts in complex agroecosystems. This project refined an existing model, DeNitrification-DeComposition (DNDC), and produced such a quantitative tool, which can be used to estimate mitigation potentials of N<sub>2</sub>O in California specific conditions. The tool has also been adopted to develop N<sub>2</sub>O emission estimates from California croplands for the 2015 California GHG inventory. Simulation of mitigation scenarios using the tool indicated that subsurface drip and surface drip irrigation, reduction of N rate by 15 percent plus nitrification inhibitor, and planting non-legume cover crops are the most effective mitigation measures, which could reduce statewide N<sub>2</sub>O emissions by 59 percent, 41 percent, 28 percent and 22 percent, respectively, compared to Business As Usual (BAU) scenarios in California.