UCR College of Engineering-Center for Environmental Research & Technology

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Center for Environmental Research and Technology

2011 ANNUAL REPORT

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Director's Message

CE-CERT reaches a significant milestone next year, our 20th anniversary. That fact has meant that many of us here are spending some time reflecting a bit on where we have been, and what we have become. It has been a terrific ride.

In the last few years, we have made strategic moves to ensure our relevance and success into future years. At the end of 2011, we have more than $10 million in research projects underway, also notable for the diversity of new and continued areas of inquiry.

Our Sustainable Fuels Research group played a key role in the completion of a landmark consortium evaluation of switchgrass as a source of biofuel (culminating more than a decade of feedstock research, including previous work on poplar wood and corn stover). The Los Alamos-based center for non-food ethanol production also scored its first technology transfer success, an invention originating in our labs. Our hydrogasification effort developed new techniques to produce substituted natural gas, and completed its new process demonstration unit, a key advance on the road to possible commercialization. They also developed and conducted for the first time a gasification training school for energy companies.

The work of the Emissions from Next-Generation Engines and Fuels continues to demonstrate field-leading capabilities for both developing and evaluating the latest technologies for reducing emissions from on-road and off-road vehicles, as well as stationary point sources.

They also attracted more than 140 experts from around the world for a first conference on new technologies under development for portable emissions monitoring systems (PEMS).

The Atmospheric Processes Laboratory continues to push the frontier of what is possible in understanding chemical processes in the troposphere. Their work is breaking old barriers in knowledge of secondary organic aerosol and particle formation. They continue to improve models of chemical mechanisms and are making significant inroads for modeling the formation of ozone, particles, as well as an increasing number of VOCs.

Our Solar Initiative completed a 'solar road map' for the City of Riverside, confirming that the city's goal of 20 MW of solar collectors is achievable, and offering advice on the economics of its success. Solar research also showed promising avenues, including phase two of the Solar Thermal Storage facility, work on lithium iron phosphate nanowires as next generation cathodes, and graphene composites to control heat in concentrated photovoltaic collectors.

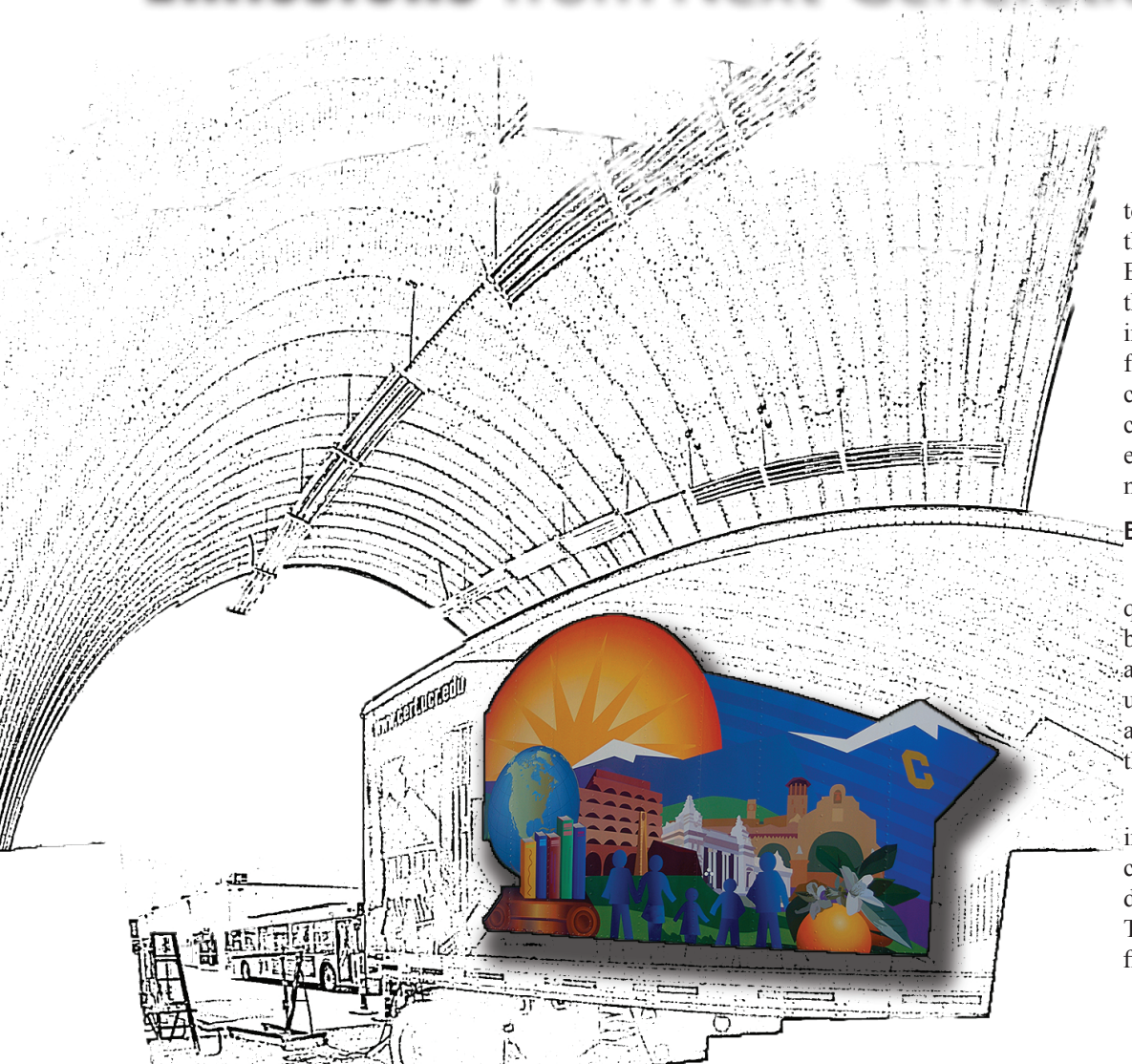
The Transportation Systems Research group extended its efforts in Eco-friendly Intelligent Transportation Systems as a partner on the U.S. Department of Transportation's AERIS research program (Applications for the Environment: Real-Time Information Synthesis). Another major research area was begun during 2011 in Eco-driving, starting with a three-year effort to develop comprehensive driver feedback technology which may save significant amounts of fuel as well as cut emissions.

These are just a few of the 2011 highlights at CE-CERT. There are many more important developments that can be found in the following pages, as well as our website at www.cert.ucr.edu.

Best Regards,

Matthew J. Barth

Emissions from Next-Generation Engines and Fuels



The path toward energy and environmental sustainability has brought to the forefront one of this century's great engineering challenges – evaluating the impacts of the next generation of fuels on our health and environment. Our Emissions from Engines and Fuels Research has focused on understanding how these fuels may impact the operation and efficiency of engines, and on comparing the environmental and health impacts of these alternatives to conventional fuels. The research has expanded to almost every sector of energy use, from cars and trucks to off-road equipment, small engines, power generators, even cooking operations. Major headway in 2011 includes the work on biodiesel emissions quantification and understanding the limitations of portable emission measurement systems.

Biodiesel

Biodiesel is an attractive sustainable option because these fuels have similar quality characteristics to middle distillate petroleum diesel fuels, and they are biodegradable, non-toxic, and free of sulfur and aromatic compounds. Biofuels also tend to have favorable emissions profiles compared to petroleum (reduced unburned hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM), and most toxic and carcinogenic compounds). The main issue with biodiesel is the potential for higher oxides of nitrogen (NO_x) emissions.

In support of the California Low Carbon Fuel Standard (LCFS), CE-CERT, in conjunction with the California Air Resources Board and UC Davis, recently conducted one of the most comprehensive studies of biodiesel emissions to date, with an emphasis on the use of biodiesel in cleaner California diesel fuel. The final report for this study was released in the fall of 2011. One of the key findings of this study was that the impact of biodiesel on NO_x emissions might

be a more important consideration when it is blended with a "clean" diesel fuel, and some form of additional NO_x mitigation would be needed for biodiesel blends with such fuels. Currently, no biodiesel formulations have met California's strict requirements for certification as an alternative diesel fuel for widespread use in the state. The next stage of this research, which is ongoing, will be to develop biodiesel formulations that have the potential to meet California's fuel certification requirements, using either low levels (i.e., B5) of more neutral biodiesel feedstocks or using additives.

Another important new area of inquiry for biodiesel research is looking at health effects of emissions. Working with experts at UC Davis, UCLA, the Desert Research Institute, and the University of Wisconsin-Madison, researchers will be looking at PM composition, speciation, toxicity, biological effects, and health effects.

Alcohols

The Emissions group is conducting research on different alcohol fuel mixtures for the California Energy Commission (CEC) and the South Coast Air Quality Management District (AQMD). The project is evaluating the power levels, fuel economy, and emissions components of hydrous ethanol, ethers, bio-gasoline, and various molecular weight alcohols. As the range of potential formulations and vehicle and engine technologies expand, it is also important to evaluate the compatibilities of different fuels with newer engine/vehicle technologies. In other words, before sustainable fuels are produced in large amounts, it is important to understand how they work in production vehicles. New flex fuel vehicle approaches continue to emerge and various alcohol fuels from an increasing number of sources also need to be evaluated for their utility and their environmental impact.

Natural Gas

Natural gas is an alternative fuel that is already widely used in California for transportation, in homes and for electric generation. Demand is expected to increase to the point that new sources of gas will need to be imported that may have different compositions. CE-CERT tested compressed natural gas (CNG) and liquefied natural gas (LNG) from various sources to evaluate their differences in power, fuel economy and exhaust emissions. In an earlier phase of this project, the Center evaluated a Ford Crown Victoria and a Honda Civic GX powered by gas mixtures with varying levels of heavier hydrocarbons and hydrogen to carbon ratios. In the summer of 2011, CE-CERT tested three more heavy-duty vehicles (two buses and a refuse hauler) on a matrix of NG blends.

Olefins in Gasoline

The Center has also conducted emissions testing for the Coordinating Research Council (CRC) to study the emissions impacts of olefins, or alkenes, in gasoline. While many fuel properties for gasoline have been thoroughly studied, the effect of olefins content has not been extensively evaluated since the Auto/Oil Air Quality Improvement Research Program 20 years ago. The results of the CE-CERT study will inform future versions of predictive emissions models maintained by CARB and the U.S. Environmental Protection Agency (EPA). Such models are used in the process of evaluating new gasoline formulations. For this study, regulated and non-regulated emissions were tested using two gasoline fuels (with olefin content of 3-15 percent) in a fleet of 15 modern gasoline-powered vehicles.

Portable Emissions Measurement Systems

State and federal regulations now are calling for in-use, real-time measurements of heavy-duty diesel vehicles, creating challenges and opportunities for air quality engineers. Until very recently, so called "EPA 1065 Certified" measurements have only been possible using very large collections of equipment, such as in laboratories or with CE-CERT's Mobile Emissions Lab (MEL). Now future in-use vehicle emission enforcement requires accurate instruments for measuring gaseous emissions and particulate matter that are small enough to be carried by the target vehicle. A number of companies are developing these new technologies — called Portable Emissions Measurement Systems, or PEMS, that miniaturize those capabilities into machines a fraction of MEL's size. Manufacturers are implementing a range of technologies to measure PM. One uses a quartz crystal microbalance to directly measure the weight

PEMS equipment, seen on the roof of this tractor, captures the behavior of hybrid equipment on a second by second basis during in-use operations at construction sites.

gain of the deposited PM mass. Another uses a combination of a gravimetric reference filter and a real-time electrical signal carried by the particles. Researchers from CE-CERT, CARB and U.S. EPA recently published the first in-use evaluation of the performance of five PM PEMS technologies compared to the fully 1065-compliant MEL. The machines performed well in some circumstances and poorly in others. The analysis found that all of the systems showed a negative bias compared to the MEL. The study also looked operational issues with the PEMS related to system set-up, calibration and software use.

CE-CERT hosted a PEMS Workshop in March of 2011 that attracted more than 140 participants from government, industry and academia interested in the capabilities of these new technologies. Sponsors included the Engine Manufacturers Association, CARB, AQMD and PEMS manufacturers AVL, Sensors, Horiba, Emisense, and Clean Air Technologies International.

A second, expanded PEMS workshop has been scheduled for Thursday and Friday, March 29-30, 2012. The first day is planned to offer presentations about the progress of the different PEMS technologies in various in-use conditions. The second-day will provide hands-on technical training on the actual machines. Last year's PEMS conference made it clear that careful training is necessary for PEMS testing to produce consistent results, according to Kent Johnson, program director of the PEMS workshops. The expanded workshop format will provide more opportunities to share best practices in using the instruments.

Off-Road Vehicle Emissions

As automobiles have been successfully engineered to reduce emissions, off-road equipment (diesel engines of 25 horsepower or greater used in construction, mining, airport ground support) have become an increasing fraction of the inventory.

A great deal of research has been conducted for on-road diesel fleets, and most of the assumptions and modeling inputs for off-road emissions have been adapted from these on-road studies. However, work at CE-CERT is demonstrating that there is actually quite a bit of difference in the operating and emissions profiles of off-road diesel vehicles. Under CARB and Caltrans funding CE-CERT is conducting work on construction equipment to measure the amount and types of operations, such as digs, lifts, and pivots, both loaded and unloaded, and to relate these operations to the emissions profiles and fuel efficiency using PEMS equipment.

Hybrid technologies are one approach to reducing emissions from offroad equipment. During 2011, CARB awarded CE-CERT's Emissions Research Group a $2 million grant to evaluate the emission reduction benefits of hybrid technology for heavy-duty off-road construction vehicles. This is part of a larger effort by CARB to expand the use of hybrid technology to help meet the goal of AB 118 — an 80 percent reduction of greenhouse gases by 2050. The use of hybrid-electric technology in heavy-duty on- and off-road vehicles is at a very early stage of development. CE-CERT is also working with CalStart to evaluate emissions from heavy-duty hybrid diesel trucks and all-electric trucks under CEC funding. The tests on the all-electric vehicles will include performance and state of charge measurements.

Certification Test Method Developed for Distributed Generation

The use of distributed generation (DG) power production (defined as units producing less than 50 MW) is expected to increase in California in response to the California Energy Commission's approach to meeting our growth in energy demands. To ensure minimal impacts to our air quality, the California Air Resources Board has implemented more stringent emissions regulations on these sources. The new DG units are now producing emissions levels below the detection level of the certification methods. CARB and CEC have funded CE-CERT to evaluate various methods for improving our ability to accurately measure these very low polluting units. The goal of the study was to obtain an accuracy of VOC, NO_x, and CO concentrations of 0.1 ppmv and exhaust flow rate within +5 percent. A 300kW Fuelcell Energy fuel cell, a 65kW Capstone microturbine, two 14 MW Solar Titan turbines with SCR and $SCONO_x$, and a 50MW GE turbine were used to evaluate potential new methods. CE-CERT proposed several recommendations based on the test results: 1) new instrument ranges for CO, CO_2, NO_x and Total Hydrocarbons (THC) for ARB Method 100; 2) U.S. EPA Method 25A with a flame ionization detector should be considered as a replacement for canister samples for measuring the hydrocarbons in the field; 3) if canister methods are continued for non-methane non-ethane hydrocarbons (NMNEHC) values <10ppm, additional zero gas samples and lower certification gas levels should be used, and; 4) additional flow checks with ISO-8178 methods that are based on a mass balance should be replaced.

Advanced Spectroscopy Research

Another important aspect of CE-CERT's emissions technology research involves spectroscopy research. This area, led by development engineer John Pisano, conducts research in the development, evaluation and application of advanced spectroscopy techniques.

The broad based deployment of post-combustion NO_x control systems, such as selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR), in response to more stringent NO_x control mandates, have highlighted the need for continuous ammonia (NH_3) monitoring capabilities. Since increased NO_x reductions can be obtained through higher injection rates of ammonia in SCR systems, the optimiza-

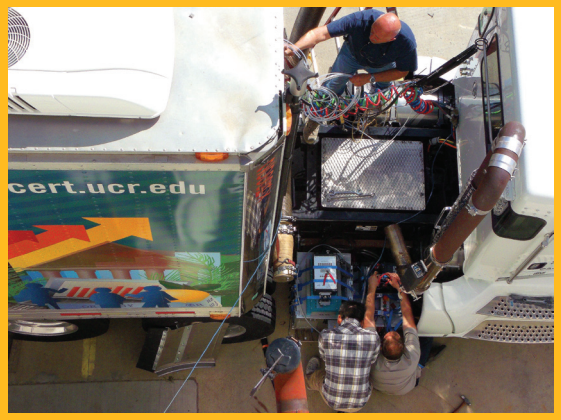
tion of NH_3 injection rates without causing undue NH_3 slip is an important consideration for power plant operators. The use of tunable diode lasers (TDLs) are used in power plant and other stationary combustion facilities to monitor NH_3 slip from SCR systems.

To date, CE-CERT has worked with approximately 15 power plant facilities on the installation, evaluation, and optimization of TDLs for NH_3 measurement. Much of this work has been funded by the Electric Power Research Institute (EPRI). Researchers have also published several studies on the applications of TDLs for the measurement of NH_3 from vehicles. With the onset of 2010 regulations requiring stringent NO_x control, and the associated increased need for SCR systems for diesel vehicles, researchers anticipate TDL vehicle applications will continue to grow.

The spectroscopy lab not only uses TDL instrumentation in the field, but is also specifically designed to evaluate and verify TDLs that are being marketed under laboratory conditions. The numerous ammonia monitors on the market have mixed reviews from end users in the field and from validation efforts. It has been determined that this can be attributable to a combination of factors, including interferences and other issues. CE-CERT's laboratory has the capability of evaluating the instruments over a wide range of conditions, including varying gas concentrations, temperatures, pressures, and moisture levels. To date, six TDL instruments have been evaluated for the measurement of NH_3, and one TDL has been evaluated for the measurement of HCl and HF.

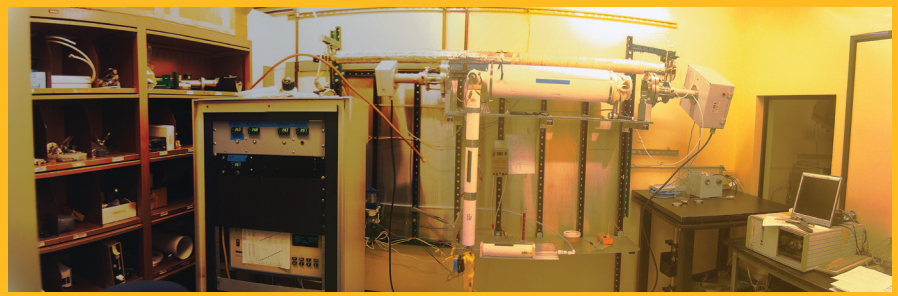
Another spectroscopy technique, Differential Optical Absorption Spectroscopy (DOAS) is being used for very low level measurements of SO_2, formaldehyde, and acrolein. Researchers are currently working with CARB to develop a DOAS for low level measurements of SO_2 in vehicle applications. SO_2 measurements can provide valuable information about the contribution of combustion and oil-derived sulfate in particles and the conversion rates found for SO_2 to sulfate. The DOAS developed as a part of this work will be installed in one of CARB's testing facilities.

The Center's heavy-duty chassis dynamometer was used in part of an AQMD project to measure criteria pollutants, CO_2, NO_2, ultrafines, NH_3, 1,3 butadiene, benzene, aldehydes from a range of on-road vehicles.

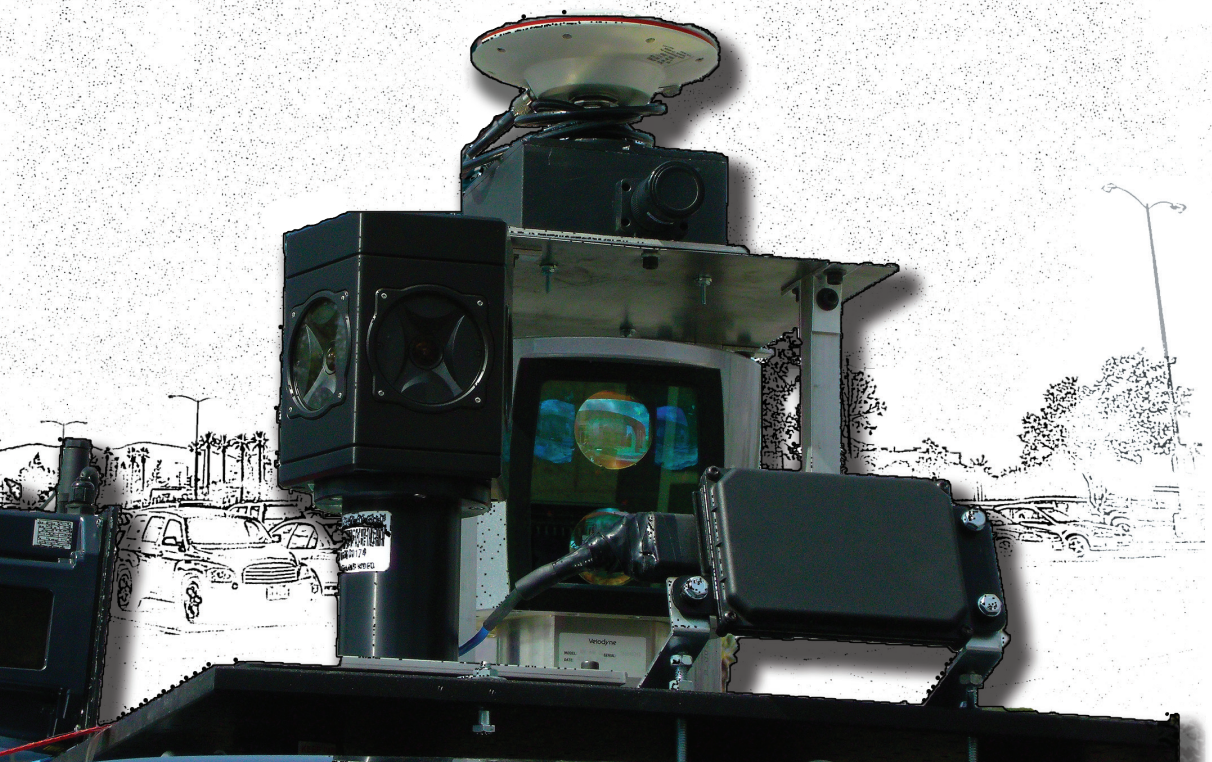


CE-CERT has continued to play a central role in the development and evaluation of portable emissions measurement systems (PEMS). A first PEMS Conference sponsored by the Center attracted more than 140 specialists in the field.

UCR has developed a laboratory specifically designed for the evaluation of commercial tunable diode laser instruments for vehicle applications. The laboratory has the capability of evaluating the instruments over a wide range of conditions, including varying gas concentrations, temperatures, pressures, and moisture levels.



Intelligent Transportation Systems Research



It is anticipated that computing, control, communication, and sensing technology will continue to transform today's vehicles and transportation systems to improve safety, efficiency, economics, and environmental/energy issues. CE-CERT has grown to become one of the key leaders in energy and environmental areas of Intelligent Transportation Systems Research (TSR). In addition, with these TSR technologies, vehicle management is no longer isolated to the vehicles themselves; vehicles and the system infrastructure are becoming increasingly integrated to address these goals. The TSR group focused on several specific applications this year:

- integrate multiple technology systems with infrastructure promoting more environmentally friendly transportation;
- provide drivers with innovative ways to drive efficiently and more economically,
- combine multiple sensors, databases, and passive and active feedback techniques to develop vehicle positioning and mapping technologies that enable lane-level transportation applications, and;
- create new ways to analyze and impact the operation of vehicles on a large scale, producing practical and research benefits.

ECO-ITS

CE-CERT's research in Eco-friendly Intelligent Transportation Systems (ECO-ITS) was very active on a variety of fronts. In general, we define ECO-ITS as using advanced technologies to improve traffic operations and driving behavior to save fuel and reduce vehicle pollution. One of the primary efforts was in the U.S. Department of Transportation's new AERIS research program (Applications for the Environment: Real-Time Information Synthesis). CE-CERT participated in four of the seven initial first round awards, examining issues of: 1) how to collect real-time vehicle environmental data that can support environmentally friendly transportation projects; 2) how to design vehicle trajectories while traveling on a signalized corridor; 3) how to estimate energy and emissions from a number of different traffic scenarios; and 4) international research being carried out in the area of energy/environmental ITS. This initial phase within AERIS was successful and results were presented at a number of conferences, including the ITS World Congress in Orlando Florida. CE-CERT then joined forces with Booz Allen Hamilton to write a winning proposal for the next major phase of AERIS, where a number of environmentally friendly transportation concepts will be formulated and demonstrated in 2012.

In addition to this activity at the federal level, CE-CERT continued its research with Nissan Motor Company, examining the efficacy of different eco-friendly technologies in their vehicles. This project is on-going and examines both simulation and real-world vehicle activity testing of their vehicles, coupled with our on-board instrumentation. Other exploratory research projects were carried out as part of the University of California's Multi-campus Research Program Initiative in Sustainable Transportation.

Eco-Driving

Closely related to our ECO-ITS research, TSR embarked on a major research effort on Eco-driving, sponsored by the U.S. Department of Energy. This $1.2 million study was kicked off in late 2011 and is focused on evaluating technologies that provide feedback to drivers so they can cut harmful emissions and reduce fuel use by up to 30 percent. The three-year project aims to develop and demonstrate comprehensive driver feedback technology that will improve fuel efficiency of passenger cars and fleet vehicles of businesses and government. This technology already exists on a small scale, but this study will make large advances in a fully integrated feedback system that includes better trip planning and routing, improved efficiency while driving, and comprehensive reporting on a periodic basis. Several small studies, including one at UC Riverside, have found fuel economy improvements in the range of 5 to 15 percent. Larger scale Eco-driving programs in Asia and Europe have shown fuel improvements up to 20 percent. This grant allows CE-CERT to go beyond small, anecdotal studies to show, on a large scale, the significant positive economic and environmental impacts

The TSR group uses advanced communication systems to broadcast signal phase and timing to the vehicle environment.

One of the workshop panels included (left to right) Alex Bayen, ITS Berkeley, Matt Barth, CE-CERT, and Wenlong Jin, ITS Irvine.

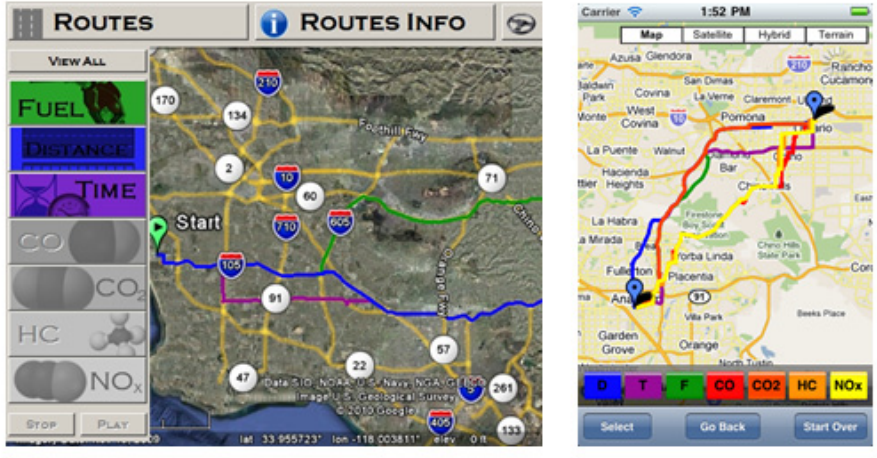
An advanced mapping and positioning system is utilized for determining centimeter-level accuracy of the vehicle and road environment.

of Eco-driving principles and the value of feedback systems. The project was one of 40 being funded through a more than $175 million program aimed to help automakers achieve new fuel efficiency standards.

In May 2011, together with UCR's sister campuses at Berkeley, Irvine, and Davis, TSR organized an Eco-driving Research Workshop, sponsored by the University of California Multi-Campus Research Program and Initiative (MRPI) project on Sustainable Transportation. The purpose of this workshop was to bring together experts in the fields of transportation, energy, policy, and programming from both the public and private sectors to critically evaluate the behavioral, technical, and policy issues associated with Eco-driving. By convening experts across North America, the meeting served to evaluate and prioritize the major research challenges and goals of this developing field.

Vehicle Positioning and Mapping

Together with Electrical Engineering Professor Jay Farrell, TSR research continues with developing the next generation of driver assistance systems in terms of vehicle positioning and mapping. During 2010 and 2011, the group conducted a broad assessment of potential sensor and infrastructure technologies that are important to reliably determine a vehicle's position at the lane-level on the road. The research is showing that only a fusion of sensors with complimentary features can truly provide reliable, all-weather, all-time-of-day, lane-level position determination. The benefits of such a technological fusion are obvious for driver assistance. However, the research also points to positive impacts on traffic congestion, mobility, energy/environmental conservation, and road way safety. In 2011 TSR developed and evaluated prototype positioning systems that integrate on-board sensors with measurements from cooperative infrastructure signals. This includes computer vision, RADAR, LIDAR, (LIght Detection And Ranging), and radio navigation sensors. As part of this research, CE-CERT was chosen as one of the recipients of the US-DOT's Connected Vehicle Technology Challenge Award.



On-board platform Mobile platform (iPhone)

CE-CERT's on board Eco-driving fuel and emissions optimization routing package.

In 2011 TSR started a research project on the complementary mapping research problem. The research team has developed a suite of sensors and post-processing algorithms to provide accurate, lane-level mapping information, as part of a project sponsored by the Federal Highway Administration. Demonstration of these results is expected in 2012.

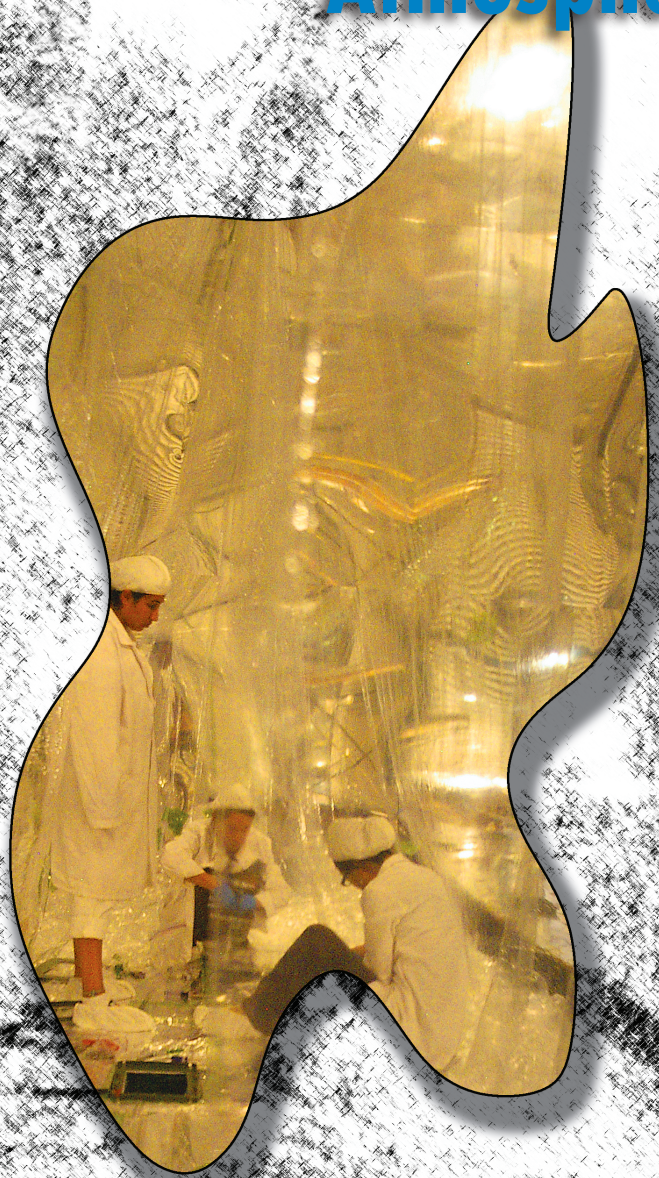
Vehicle Activity Research

Understanding vehicle activity continues to be a core research interest at CE-CERT. During 2011, the group was active in developing and deploying Caltrans' fleet tracking system of alternative fueled vehicles. The developed system includes on-board monitoring hardware that has telematics capabilities based on an open architecture and non-proprietary system that will allow maximum ease of integration and expansion of the Caltrans fleet and the addition of more intelligent transportation system applications.

In addition to this telematics research, the TSR group embarked on two other projects to measure vehicle activity and estimate their energy and emissions impact. One project was in conjunction with UC San Diego (sponsored by the University of California Transportation Center) where computer video information was used to dynamically predict energy and emission levels by simply observing traffic. This was one of the first studies that used computer vision algorithms to: 1) count the total number of vehicles in the video scenes; 2) detect and classify the vehicles; and 3) track their overall movements.

The group also investigated estimating vehicle energy and emissions by obtaining data from sensors placed in the roadway infrastructure. Together with Sensys Networks who has developed unique traffic sensors that are placed in the pavement, the research allowed data analysis to re-construct vehicle trajectories, and then estimate their energy and emissions based on those trajectories. As our roadway sensor systems continue to advance, the algorithms that were developed in this project can be used to provide feedback on the energy and emission costs associated with a variety of traffic management techniques.

Atmospheric Process Laboratory



Air quality in the United States has improved markedly since the Clean Air Act of 1990 led to cost-effective regulations that current science can support. But there are still many areas of this country, including much of Southern California, that do not yet meet National Ambient Air Quality Standards. For instance, California Air Resources Board estimated that more than 90 percent of Californians are exposed to unhealthy levels of one or more air pollutants during some part of the year (ARB Fact Sheet: Air Pollution and Health, 2009). Most of the easy regulatory work has been done, according to David Cocker, professor of chemical and environmental engineering at UCR/CE-CERT. What remains to be cleaned up will take new approaches, new tools and advanced technology to push the frontier of knowledge of atmospheric processes.

The Center's Atmospheric Processes Laboratory (APL) has been a cutting-edge contributor to that effort. APL's indoor environmental chamber is one of the most advanced facilities in the world for the study of chemical processes in the troposphere. Based on the advancement on the understanding of gas-phase ozone chemistry primarily led by William Carter at UCR/CE-CERT over more than 20 years, APL has made much progress on understanding PM formation from a number of significant classes of hydrocarbons, such as aromatic hydrocarbon, isoprene, and amines, just to name a few.

Fine particle pollution has long been a key environmental concern with far ranging impacts, including its role in climate forcing, negative health impacts, and poor visibility. Secondary organic aerosol (SOA), formed from the oxidation products of certain biogenic and anthropogenic volatile organic compounds (VOCs), continues to be a significant component of rural and urban fine particulate matter, with estimates of SOA contributing up to 80 percent or more of the organic aerosol loadings. Accurate predictions of SOA formation from gaseous precursors at local and regional scales require a detailed understanding of the chemical mechanisms leading to the formation of condensable organic species. These chemical mechanisms can then be integrated into regional and global atmospheric models to accurately

predict SOA formation and its environmental impacts. The most recent research at APL for each pollutant is described below.

Experimental Studies on SOA Formation

The CE-CERT environmental chamber is one of the best places in the world for the study on SOA formation since experiments can be carried out under atmospherically relevant conditions with precise control of environmental parameters, ruling out the effect meteorology and the direct emission contribution. The environmental chamber is equipped with two 90 m^3 teflon reactors contained in a temperature controlled enclosure which is continuously flushed with purified air. Black lights or an argon arc lamp are used to simulate the ambient radiation. APL is also equipped with a series of online and offline chemical analysis instruments to measure various gas phase compounds, physical and chemical properties of aerosol, including particle volume concentration, density, volatility and chemical composition.

Aromatic hydrocarbons

Aromatic hydrocarbons are an important class of VOCs in the urban area and it contribute to ~20% of non-methane hydrocarbons in the urban atmosphere. These compounds are highly reactive and known to be significant contributors to SOA formation. Yet the underlying mechanism of SOA formation is elusive because the chemical reaction pathways of aromatics are complex, and resulting oxidation products are both numerous and difficult to quantify analytically. The group recently completed a major effort to test individual aromatic compound in the CE-CERT chamber. The goal is to discover the precise mechanisms that control the formation of particles.

In one study Ping (Annie) Tang, Shunsuke Nakao, and Li Qi et al. investigated the SOA formation using a range of individual aromatic hydrocarbons. It is observed that under low-NOx conditions aerosol formed from aromatic hydrocarbon with more carbon atoms has a lower SOA yield. Utilizing an aerodyne high resolution time of flight aerosol mass spectrometer (HR-ToF-AMS), they observed a decreasing trend of O/C ratio with increasing number of alky groups. Measurements from AMS also indicated more ketone over aldehyde was formed from aromatics with more alky substituents. Ketones are harder to oxidize than aldehydes and therefore go through lesser oxidation thus result in a lower aerosol yield.

A series of chamber studies by Shunsuke Nakao and Ping Tang et al. investigated SOA formation mechanism of aromatic hydrocarbons by evaluating the significance of first-generation reaction products. Photooxidation of aromatic hydrocarbons produces a wide-range of products including ring-retaining compounds (e.g., phenolic compounds) and ring-opening compounds (e.g., glyoxal). First, Nakao et al. carried out a series of chamber experiments using phenolic/aromatic compounds using the CE-CERT indoor chamber and experimentally estimated that approximately 20 percent of aromatic hydrocarbon SOA is formed via oxidation of phenolic compounds under low NO_x conditions. Their unique approach, as well as chemical analysis using advanced mass spectrometers, provided new insights on the poorly understood SOA formation mechanism from aromatic hydrocarbon oxidation. Next, Shunsuke Nakao, Yingdi Liu, and Ping Tang et al. evaluated the role of glyoxal in SOA formation from aromatic hydrocarbons; glyoxal is an abundant species in the atmosphere produced by oxidation of a number of VOCs including aromatic hydrocarbons. Previously, glyoxal (CHO-CHO) was not considered to be a significant source of SOA due to the extremely high vapor pressure of glyoxal and its reaction products (about one million times too high). However, recent studies suggested glyoxal can partition to aqueous phase of PM (process called “glyoxal uptake”) and form SOA via formation of low-volatile compounds via aqueous reactions. The study by Nakao et al. showed that glyoxal can produce SOA via aqueous reaction when there is enough water in particles (e.g., wet ammonium sulfate particle); however, glyoxal uptake onto SOA was negligible due to limited availability of water and electrolytes in particles. This study demonstrates the significance of glyoxal uptake is strongly dependent on the particle composition and likely to be overestimated in current atmospheric models.

Isoprene

Previously, SOA formation from isoprene (C_5H_8), the atmosphere’s most abundant non-methane hydrocarbon, was considered insignificant due to its small number of carbon and high vapor pressure. However, recent studies on isoprene oxidation suggested that vapor pressure of some of the oxidation products of isoprene are low enough to condense onto preexisting PM, as well as oligomerization in particle phase results in formation of low-volatile compounds. Chamber studies by Christopher Clark, Kei Sato, and Shunsuke Nakao et al. investigated SOA formation processes from isoprene and other conjugated dienes in the environmental chamber with precisely controlled environmental conditions. These studies demonstrated that isoprene significantly contributes to SOA formation and environmental parameters such as temperature can greatly impact the amount of SOA formed as well as its chemical composition.

Amines

Agricultural emissions are an important class of emissions that are often overlooked in terms of their role in SOA production. Very little work has focused on the atmospheric chemistry or the SOA formation from amines, a significant class of compounds released from agricultural operations. Numerous studies have shown that significant concentrations of amines are present near agricultural facilities such as dairies, feedlots, and other animal feeding operations (AFOs). The mechanism for amines depositing into particles is absent in chemistry models of regional air pollution and is also ignored from a global biogeochemical perspective of the nitrogen cycle. Models to estimate ozone and aerosol formation from this class of compounds require careful

investigation of their atmospheric chemistry under highly controlled experimental conditions. We use CE-CERT's 12.5 m^3 reaction chamber to simulate oxidations of primary (butylamine), secondary (diethylamine), and tertiary (trimethylamine) amines by nitrate radical and hydroxyl radical, under dry and humid conditions (RH=30-50%). A set of online and off-line instruments are used to monitor evolution of gas- and particle-phase aerosols. Necessary parameters have been developed to estimate the aerosol formation potential of these three kinds of amines. The ability of aerosols impacting global climate by acting as cloud condensation nuclei (CCN) is also explored. Results show that aerosol formed from diethylamine and butylamine with NO_3 are very hygroscopic, in other words, have great potential of becoming cloud droplets in the atmosphere. This is the first research into the hygroscopicity of aliphatic amine aerosol. These results will significantly impact the estimation and role of amines in atmospheric chemistry and global climate models.

Modeling

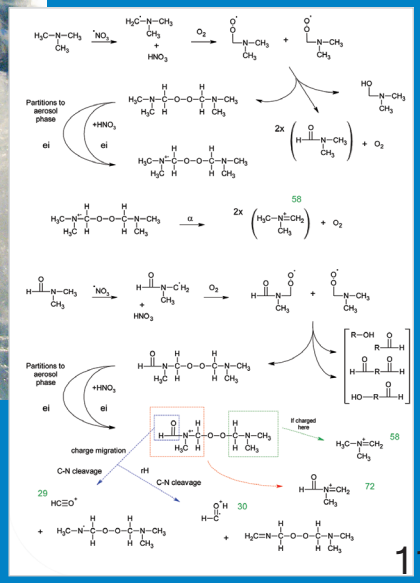
The gas-phase reaction model SAPRC07 was developed by William Carter to determine absolute and relative ozone impacts (reactivities) of VOCs that can be emitted into the atmosphere, and for other control strategy and research applications. Compared to SAPRC-99, SAPRC-07 optimized the uncertain parameters in aromatic mechanisms to give better simulations of results of the photooxidation of aromatics in environmental chambers, and also gave generally good results of incremental reactivity experiments with aromatics.

According to the study by Gookyoung Heo, Shunsuke Nakao, and Ping Tang et al., the new mechanism model (PM-SAPRC) reasonably simulated both O_3 and SOA formation for most of 22 aromatics studied; the fits of model calculation to measured PM levels are generally in the range of a factor of two, compared to the generally ~30% scatter observed for modeling ozone formation in chamber experiments. SOA formation routes via phenolic intermediates and bicyclic peroxides were simulated to be major contributors to SOA formation from aromatics.

SAPRC is one of the few atmospheric reaction mechanisms used for regulatory purposes around the world. Wendy Goliff, assistant research engineer at CE-CERT, has played an important role in developing the Regional Atmospheric Chemistry Mechanism, Version 2 (RACM2). EPA's Atmospheric Modeling Division is considering both SAPRC and RACM2 for inclusion of the next public version of CMAQ (the Community Multiscale Air Quality Modeling System).

CE-CERT's Georgios Karavalakis (left to right) and David Cocker pursued a growing interest in health effects studies with Arthur K. Cho and John R. Froines of UC Los Angeles.

The Teflon reactors in the atmospheric chamber were redesigned to last longer and to make their interior surfaces less reactive.



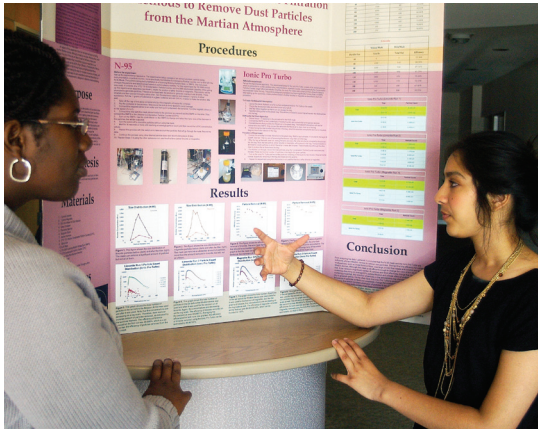
Chemical mechanisms of aerosols are developed and tested in chamber experiments, yielding elaborate documentation of their 'fate,' in this case, of trimethylamine.

Black Carbon

Akua Asa-Awuku, Assistant Professor of Chemical and Environmental Engineering, began a three year study of how black carbon aerosol impacts both climate change and human health. Funded by a U.S. EPA STAR (Science to Achieve Results) Faculty Grant, the research seeks to better understand how man-made pollutants affect the mechanism of wet droplet formation, both in our lungs and in the atmosphere. When carbonaceous fuels are burned, black carbon (BC) PM is emitted, as well as organic carbon (OC) compounds that are lighter in color. These latter particles are known to serve as seeds (nuclei) for droplet formation.

Black carbon particles are insoluble, Asa-Awuku said, but organic carbon compounds react readily with water vapor. The mechanism of how the two types of carbon species interact in droplet formation is little understood and may have broad impacts on issues ranging from climate change to human health. While PM pollution has already been tied to health problems, the mechanisms that lead to adverse health effects are not well understood, she explained, and understanding how particles behave and grow in our lungs, and environment, is vital.

To study climate impacts, Asa-Awuku makes optical measurements utilizing the reflective properties (color) of carbonaceous aerosol. Organic carbon compounds can appear lighter in color than black carbon. Depending on how light or dark they are, the particles can have either a cooling (scattering) or warming (absorbing) effects in the atmosphere. In addition, the chemical composition of the various colored particles can be extremely different and can differently affect their climate impacts.



King High School Junior Tulsi Shah was the latest student working with Dr. Asa-Awuku to qualify for the California Science and Engineering Fair. Her participation was supported by a gift from the Bank of America Charitable Foundation. She combined her career aspirations for astronomy and medicine by investigating engineering processes that could turn the Martian sky blue and breathable for humans.

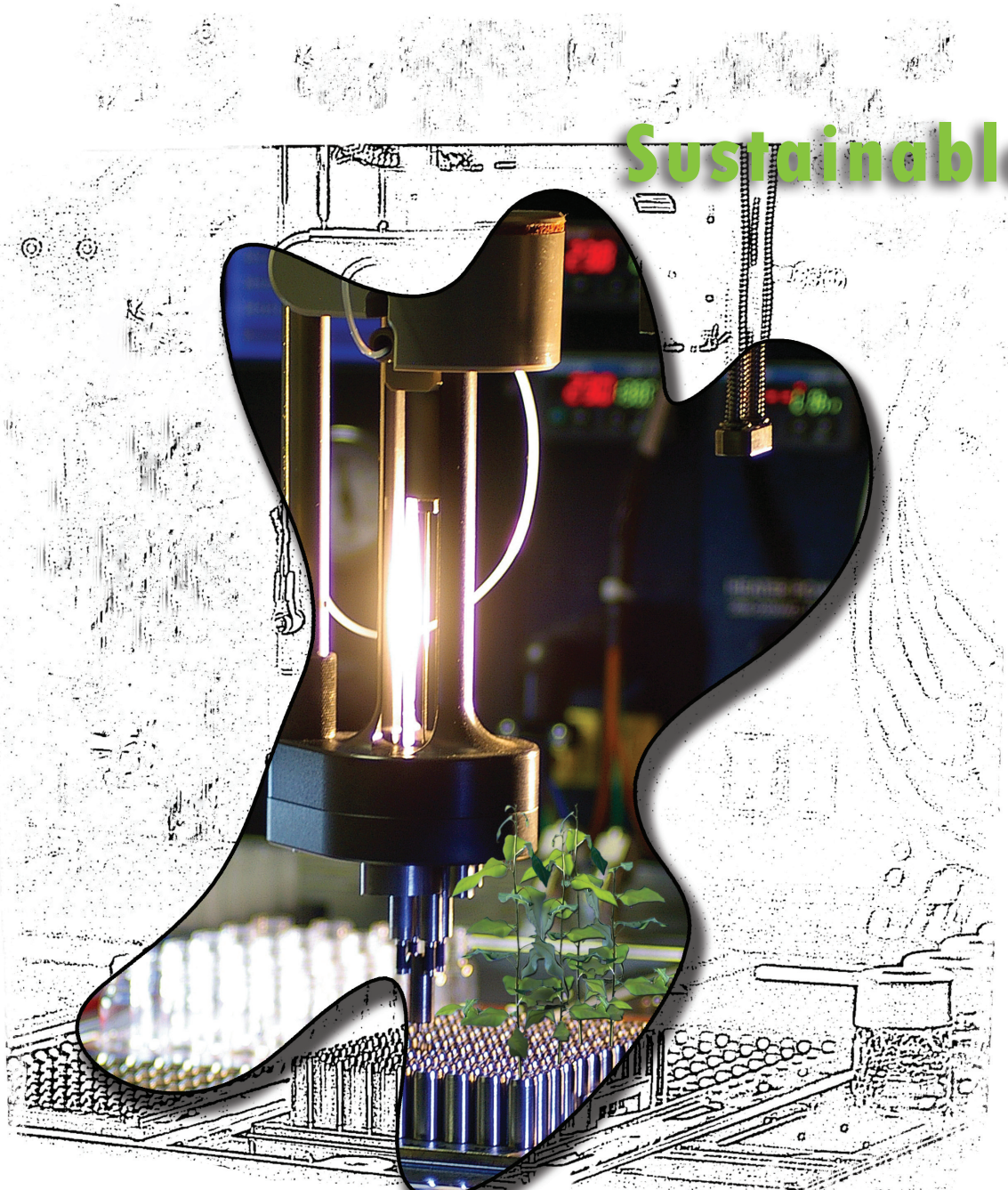
"Particles in the atmosphere that affect your health also affect the climate," Dr. Asa-Awuku said. The same nucleation principles for wet droplet growth apply to cloud formation: water vapor condenses on particles to promote droplet formation. In this way, Asa-Awuku hopes that her research will contribute to our understanding of both health and climate change. In addition to the advanced Atmospheric Processes Laboratory at CERT, Asa-Awuku will also draw on the expertise of the Center's Emissions group to measure the in-situ cloud droplet formation ability of black carbon emissions from engines burning various diesel and biodiesel fuel blends.

Field Studies

Chemical mechanisms are developed and tested and fed into models to forecast emissions over geographic regions. Field studies test and improve model's performance. The APL group completed the Paints and Architectural Coatings Environmental Study (PACES) study begun in 2006 and funded by the National Paint and Coatings Association, an industry organization.

The group developed an analytical system that proved capable for the first time of detecting TPM (2,2,4-trimethyl, 1,3-pentanediol monoisobutyrate) in ambient air. TPM, sold under the trade name of Texanol, is typically the most abundant VOC used in water-based architectural coatings. TPM was detected in all samples taken from ambient air in Riverside, Pico Rivera and Azusa ranging from 5-40 ppt. The study concluded that unreacted TPM constitutes approximately 0.01 percent of the total non-methane hydrocarbon concentrations in the LA air basin and given its slow reactivity rate in forming ozone, this would be an approximate upper limit for the fraction of ozone that it is responsible for forming.

Wendy Goliff is also working with the Desert Research Institute in Reno, Nevada to conduct a study of the Lake Tahoe air basin. The study will monitor volatile organic compounds (VOC) and carbonyl compounds and measure concentrations of NH_3, HONO, HNO_3, SO_2 and fine particulate NH_4NO_3 and $(NH_4)_2SO_4$. These data will be used for development of an air quality model to predict ozone and other secondary pollutants formation in the Basin. This work will also support the development of science-based management strategies aimed at improving air quality and ecological sustainability of Lake Tahoe.



Sustainable Fuels Research

The unparalleled task of supplying clean, reliable, and affordable energy for the coming generations has prompted an array of organizations – from industry, non-governmental organizations, and federal and local governments – to dedicate resources to improve the economics of producing renewable fuels. The Sustainable Fuels Research Group at CE-CERT has participated in this front by developing two major research labs focused on advanced fuels research and development: a laboratory centered on cellulosic ethanol research headed by Professor Charles Wyman, and the steam hydrogasification lab headed by Professor Joseph Norbeck and Chan Seung Park. The laboratories focus on overcoming the basic engineering challenges of understanding the structure, properties and potential of biowaste and other available feedstocks. Success in this area could open the door to vast supplies of sustainable energy, including diverting biomass and other carbon-containing refuse from landfills. Described below is a summary of major research efforts underway in 2011.

Cellulosic Biomass Conversion (CBC) Group

The U.S. Department of Energy-sponsored project by the Biomass Refining Consortium for Applied Fundamentals and Innovation (CAFI) was completed, providing comparative performance data on the biological conversion of switchgrass, a leading candidate as a non-food feedstock for large scale ethanol production. This four year project was preceded by two other CAFI projects which provided similar in-depth evaluations of leading pretreatment technologies integrated with enzymatic hydrolysis to release sugars from corn stover (2000-2004; CAFI-1) and poplar wood (2004-2008; CAFI-2).

Wyman, the Ford Motor Company Chair in Environmental Engineering at CE-CERT, served as the principal investigator for CAFI 3 that included colleagues from Michigan State, Texas A&M, Purdue, and Auburn Universities and the National Renewable Energy Laboratory (NREL). Corporate partners provided switchgrass (Ceres, Inc.) and enzymes (Genencor International). A collection of papers documenting the results for this switchgrass research were recently published together in a special issue of Bioresource Technology journal. The CAFI team has published many other papers on the three CAFI projects as well.

Six pretreatment processes (ammonia fiber expansion (AFEX), dilute acid (DA), lime, liquid hot water (LHW), soaking in aqueous ammonia (SAA), and sulfur dioxide-impregnated steam explosion (SO_2) were evaluated in the CAFI projects and found to produce similar yields of sugars plus sugar oligomers from pretreatment and enzymatic hydrolysis. However, the balance between monomers and oligomers varied considerably among the six pretreatments. Because most fermentative organisms cannot directly ferment oligomeric sugars into ethanol or other fuels, the development of microorganisms that can do so would be vital to full utilization of the sugar stream from pretreatment that favored oligomer release. Otherwise, alternative methods would be needed to convert the oligomers into fermentable sugars.

The maximum theoretical ethanol yield from the switchgrass employed in the CAFI project was calculated to be 87.7 million gallons per year. The minimum ethanol selling price that covers both cash costs and return on investment was projected to be $2.74 to $4.09 per gallon, depending on the pretreatment used. But with a method to ferment oligomeric sugars, the projected price would drop to $2.32 to $2.94 per gallon. Like most industrial scale ventures, buy-in costs to establish cellulosic ethanol production are high, with capital costs estimated from the CAFI 3 switchgrass at between $325M to $385M for up to an 87.7 million gallon per year facility. The pretreatment, enzymatic hydrolysis, fermentation, and recovery sections of the process were projected to be responsible for slightly less than half of the total direct fixed capital. The boiler system to recover heating value of residual biomass and lignin is estimated to be about one-third of total direct fixed capital cost.

The cellulosic biomass conversion group was also honored for commercialization of an invention developed under a project funded by the BioEnergy Science Center (BESC) through Oak Ridge National Laboratory (ORNL). BESC is a U.S. Department of Energy Bioenergy Research Center supported by the Office of Biological and Environmental Research in the DOE Office of Science for $25 million annually over five years starting in 2007, with UCR having responsibility for leading BESC pretreatment research. The award recognized the successful licensing of a method for simultaneously evaluating multiple samples (minimum 32) for sugar yields rather than the previous one-at-a-time, labor-intensive practice. Screening for optimal combinations of biomass types, temperatures, acid concentrations, enzyme doses, enzyme loadings, and other variables is central to BESC's objectives to identify and develop plant traits and microbial systems that can make it more affordable to produce ethanol and other fuels from low-cost cellulosic biomass.

The CBC team received the first BESC License Execution Award after the technology was successfully licensed to Aspen Machining, a precision machining company located in Lafayette, Colorado. Wyman, who is also a professor in the UCR Chemical and Environmental Engineering Department, Michael Arciero, of UCR's Office of Technology Commercialization, Michael Studer (a former UCR post-doc) and Jaclyn DeMartini and Heather McKenzie (UCR grad students) were recognized for the commercialization of the device at the Fifth Annual BESC Science Retreat that was held on July 18-21 in Chattanooga, Tenn.

Other CBC work this year highlighted the need to understand how to achieve maximum sugar release with low doses of expensive enzymes. Working with ORNL and NREL researchers, CE-CERT reported surprising results in the April issue of the Proceedings of the National Academy of Sciences about the influence of lignin in pretreatment of poplar. Lignin is a complex polymer in the cell wall and the chief non-carbohydrate constituent of wood. This material plays a major role in biomass recalcitrance, or resistance to the release of sugars from cellulosic biomass. The team reported that certain characteristics of ligin in poplar, such as a high S/G ratio (syringyl and gualacyl, two of the main building blocks of lignin) produced higher sugar release than a low S/G ratio. Samples with the highest sugar release belonged to a group with average S/G ratios and lignin contents. The study also discovered that certain poplar samples produced unusually high sugar yields from the cellulose in poplar but limited sugar yields from hemicellulose with no pretreatment. Given the high cost of pretreatment, future reserearch will focus on how to reduce the recalcitrance of plants so that little if any pretreatment is required to achieve high sugar yields. Such advances would support low-cost production of liquid transportation fuels.

The Defense Advanced Research Projects Agency (DARPA) funded additional research by a multidisciplinary team led by the University of Massachusetts-Amherst that included the University of Wisconsin-Madison, the University of Delaware, and CE-CERT CBC to produce renewable jet fuel from lignocellulosic biomass. The UCR Team converted the cellulose and hemicellulose in biomass into levulinic acid and derivatives that the other members catalytically upgraded to jet fuel. A key goal of this work was be to improve the technology to enable commercial production of jet and diesel fuel at $2 per gallon, assuming biomass costs of $50 per ton.

The CBC team continued research to understand and advance technology for continuous hydrolysis and fermentation of pretreated biomass to ethanol. Although continuous operations promise lower costs, limited understanding of the process is hindering effective application. Therefore, the team is conducting continuous Simultaneous Saccharification and Fermentation (cSSF) analyses of cellulosic biomass to provide a foundation for the design, evaluation, and implementation of continuous processes that could offer much lower cost than existing batch operations. Leading fermentative organisms were evaluated for use in the SSF environment, and the most promising were selected for use in cSSF. Continuous SSF runs were then made on a pretreated corn stover using stirred fermentors connected in series with substrate continuously fed to the first reactor through dip tubes with air bubbles added to avoid problematic biomass settling. Ethanol yields, concentrations, and volumetric productivities were determined for various residence times and enzyme additions and compared with batch systems. Kinetic models were then applied to identify promising operating strategies for cSSF as well as other configurations. Both single and multistage continuous systems gave better performance than batch operations at the same enzyme loading, residence time, and temperature, supporting the potential benefits of continuous operation. In addition, higher ethanol volumetric productivities, yields, and concentrations were possible from the continuous system at the same enzyme loading.

In June, the CBC Team was selected for the Western Regional Center of the Sun Grant Initiative, a national network of land-grant universities and federally funded laboratories working together to further establish a biobased economy. The goal of this project is to understand, improve, and develop advanced reaction-separation technologies that enhance yields of reactive intermediates from the hemicellulose and cellulose in biomass for cost effective conversion into drop-in hydrocarbon fuels. Performance data will be developed for reaction-separation technologies for better recovery of reactive intermediates from hemicellulose and cellulose in biomass. Kinetic models are then applied to quantify key limiting factors. The models will be optimized for temperatures, solids concentration, separation strategy, and component recycle when integrated with leading catalytic conversion reactions.

A group of scientists and engineers sponsored by the Korea New & Renewable Energy Association (KNREA) traveled to CE-CERT for a six-day coal gasification training program. KNREA promotes and certifies alternative energy development in South Korea.

A new process demonstration unit was completed at CE-CERT, a 14-foot reactor is designed to continuously process five pounds of mixed carbon feedstock per hour.

A high-throughput technique developed at CE-CERT employs an automated system loading a reactor block of up to 96 small vials allowing rapid pretreatment and hydrolysis of biomass samples. The method was patented and licensed, earning the Cellulosic Ethanol Pretreatment Lab the first technology transfer award of the Bioenergy Science Consortium.

In late 2011, the CBC Team began a new project funded by the National Renewable Energy Laboratory (NREL) to characterize hemicellulose derived oligomers that are released during water-only (hydrothermal) and low-severity, dilute acid pretreatments of cellulosic biomass. The project also includes developing approaches to effectively convert these long oligomer chains to monomeric sugars that can be more readily fermented to ethanol and/or other reactive intermediates such as furfural.

The Southern California Air Quality Management District committed to fund a study of biofuels production potential of indigenous California plant species starting in early 2012. The state is exploring home-grown alternatives to imported corn or cane sugar ethanol supplies as demand for the gasoline additive grows. The California Air Resources Board has already increased the level of ethanol permitted in gas to 10 percent, and legal requirements to reduce carbon emissions will also increase demand.

Steam Hydrogasification Reaction Laboratory

A process demonstration unit (PDU) of the Steam Hydrogasification reactor (SHR) was completed during 2011 with the help of a $1M grant from California Energy Commission's (CEC) through its Public Interest Energy Research (PIER) Program. The 14-foot reactor is designed to process five pounds of mixed carbon feedstock per hour. The new design is an advance over previous reactors within the CE-CERT Gasification Laboratory because it is for continuous operation rather than batch production.

CEC provided a second phase of funding ($ 0.6M) to continue development of this technology. This research has shown that the CE-CERT gasification process can produce high levels of substituted natural gas and liquid transportation fuels from sustainable resources and wastes. California imports more than four-fifths of the $19 billion the state spends on natural gas (2006). Local production for in-state use would be a major benefit to California's economy. It is estimated that natural gas production by the CE-CERT technology could save Californians as much as $606 million per year.

Several other research projects are now being considered for future CEC funding. One is to use a calcium-based sorbent in the SHR to capture CO_2 as it is formed. In-situ CO_2 capture changes the equilibrium to promote even more energetic gas production than otherwise possible. This capture method is being applied to the CE-CERT process to get increased hydrogen production while minimizing CO_2 emissions. The sorbent material is circulated to a second reactor where it is decomposed to CaO. The sorbent is then returned to the first reactor for continuing sorption enhanced operation. Methane is the major product of the reaction with small amount of CO and other hydrocarbons.

The CE-CERT process can also use the CO_2 as a feed stock for the production of microalgae. Algae are an excellent feedstock for the SHR. Water is essential to the SHR and the wet algae do not need to be dried or pressed before processing. The production and gasification of algae could be an important process addition in the next major project which is a five ton-per-day pilot plant process demonstration research unit proposed to be located at the City of Riverside's waste water treatment plant. An analysis of the waste water bio-solid as a SHR feedstock showed that carbon conversions rates of 70 percent could be achieved.

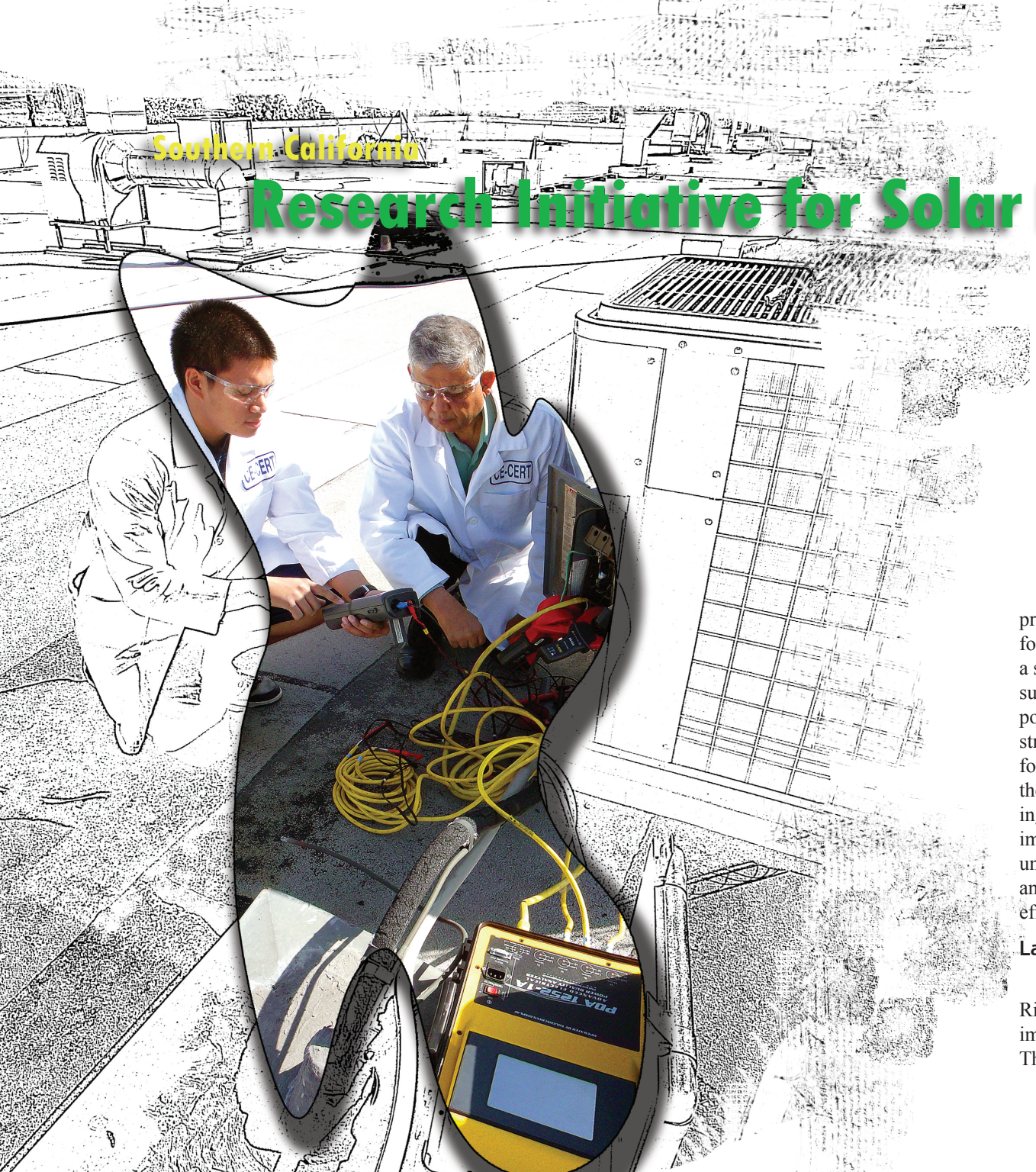
In other developments during 2011, the group prepared an economic assessment of the CE-CERT technology for publication. The assessment evaluated optimum temperature to maximize fuel production at minimal energy cost. The engineering designs for a new sulfur capture technology were also prepared for publication.

UCR Chancellor Timothy A. White noted the importance of expanded research on sustainable processes on May 2 during a ceremony to extend a research cooperative agreement in Thailand. "We have put a lot of emphasis on sustainability in our strategic plan," White said. "A lot of our success depends on our ability to generate and store energy and we have some of the best minds in the world working on it here. This is an important day and we have a lot of important work to do."

The SHR laboratory also received a 2011 Discovery Grant to explore the use of food waste as a source of liquid transportation fuel. Large scale food-serving and food-handling facilities, such as military installations, every day produce large quantities of pre-sorted, high energy, food wastes that pose human health risks. The grant promotes a partnership with Food Recycle Science (FRS) of Irvine, California which has developed a proprietary process (eCorect™) for the hydrothermolytic decomposition of food wastes at large scale food-serving and food-handling facilities.

The concentrated biomass produced by FRS is being evaluated as a feedstock for CE-CERT's SHR reactors. "It could be a very happy marriage of clean technologies," according to Chan Seung Park, associate research engineer at CERT. "A number of clean fuels could be produced which are carbon neutral and turn landfill waste into renewable energy."

The partners will work to integrate the two technologies over one year. Their first goal is to evaluate the optimum makeup (moisture content and particle size) of the feedstock. They will then measure the carbon conversion efficiency of the process in the CE-CERT laboratories. Using lab experiments and computer simulations, the final step will be to calculate the economic return of the production of different energy types (synthetic diesel, natural gas, or electricity) which can be produced by the process.



Southern California

Research Initiative for Solar Energy

CE-CERT's mission to contribute to improved environmental quality and energy efficiency has prompted the formation of CE-CERT's newest research area focused on solar energy. The potential of solar technologies as a solution to our energy needs is apparent, especially in hot, sunny Southern California. However, cost and efficiency still pose significant obstacles to solar energy becoming a mainstream solution. The Southern California Research Initiative for Solar Energy (SC-RISE) is specifically poised to increase the effectiveness of capturing the sun's energy by improving the materials solar panels are made of, understanding and improving the systems which it is delivered and stored by, and uncovering the unforeseen challenges of large grid deployment and integration with existing infrastructure. This year, research efforts have focused on several areas.

Large Scale Deployment Research

During 2011, SC-RISE completed its solar road map for Riverside — an analysis of the physical and economic factors impacting the widespread adoption of sustainable solar energy. The analysis demonstrated that conditions are favorable for

the City of Riverside to meet a goal of 20 MW of photovoltaic installations by 2020. Riverside Public Utilities (RPU) has already achieved in the neighborhood of 6.3 MW of solar collectors through their rebate programs over the past several years.

Residences account for 22 percent of the best case installations on the SC-RISE solar map. The report presented only the lowest hanging fruit, properties with the most optimal characteristics to ensure maximum return. The evaluation considered only roofs of sufficient size for 3-5 kW installation in areas with sufficient average incomes. The analysis also considered rigorously optimal characteristics including southern exposure, no shading, none adjacent to dust from vacant lots, an no installations visible from the street. A review of satellite images of Riverside found 1,100 residences, or just over one percent of residential rooftops in 28 neighborhoods, meet these criteria.

Another 29 percent of the solar energy goal could be accommodated by 23 kW-size installations on less than three percent of Riverside's commercial establishments. These candidates would be free of physical constraints, including air handler units, sky lights, roofing material, older roofs, roof load rating, parapets, and wind damping structures. Leased and subdivided structures are also not included due to the cost of installing individual meters. Finally, the remainder of the city's solar energy goals would be met by a small percentage of the RPU's 900 industrial customers.

The key to success under current economics is to adopt or develop innovative financing arrangements that reduce installation costs well under $10/watt. Already Assembly Bill 811 allows homeowners to pay for PV systems over 20 years by property tax rebates. Power purchase agreements allow investors to lease roof space for PV systems. Feed-in-Tarrifs (FiT) have proven successful in several countries in which utility companies purchase excess power generated by solar collection. The major drawback of FiTs is that solar power is purchased at a higher rate than for power generated by coal and gas. Ultimately, new mechanisms accounting for the benefits of cleaner, sustainable, domestic energy must be developed to remove the full burden from the utilities.

Materials Research

SC-RISE Managing Director Alfredo A. Martinez-Morales was funded by the Winston Chung Global Energy Center to study lithium iron phosphate ($LiFePO_4$) nanowires as the cathode material for next generation micro-batteries. The search for stronger and longer-lasting Li-ion rechargeable batteries has focused on advanced materials to decrease cost and keep them from overheating.

Martinez-Morales will develop electrochemical procedures to grow $LiFePO_4$ nanowires where their size, morphology, crystallinity and electrochemical properties can be controlled. The manufacturing process will attempt to grow $LiFePO_4$ nanowires encapsulated with a carbon layer.

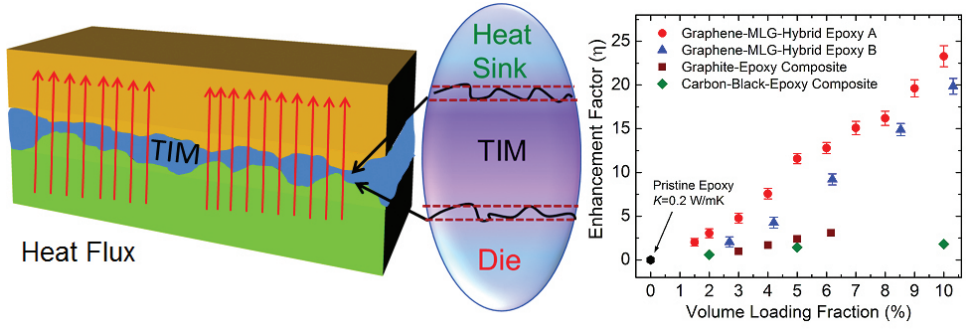
Although $LiFePO_4$ is a relatively poor conductor, its specific capacity and its flat voltage make it a good candidate for electrode research. Adding a carbon coating would improve its conductivity and iron is non-toxic compared to nickel and cobalt which are now employed in lithium ion battery chemistry.

$LiFePO_4$ also occurs as a common mineral, triphylite, which could reduce cathode costs between 10-50 percent.

The nanowires will be synthesized by chronoamperometry; using a template assisted electrochemical deposition process in ionic liquid media. By optimizing the etching conditions of the polycarbonate template it is possible to obtain NWs that are coated with a thin layer of carbon material.

The characteristics of the nanowires will be analyzed and optimized by adjusting the manufacturing parameters. The cathode material will be incorporated into continuous, practical and real-time battery system applications and progressively scaled up - from small electronic applications to those requiring greater energy densities and faster charging/discharging rates.

SC-RISE was also awarded a UC Discovery Grant to investigate ways to improve the thermal management of concentrated photovoltaic (CPV) collectors. CPVs concentrate large amounts of sunlight onto a small area of solarvoltaic material with the potential to generate many times more electricity. CPV systems can be more ef-



One goal of SC-RISE research is to produce practical thermal interface materials that will keep solar concentrators from overheating.

ficient and more economical than other photovoltaic systems, but excess heat collection on the cells in sunny dry climates decreases its efficiency. The goal of this work is to manage the thermal effects of concentrating the energy, allowing CPV to replace conventional PV.

Working with Alexander Balandin, professor of electrical engineering and founding chair of the materials science program at the Bourns College of Engineering, this project proposes to develop a low-cost, scalable method for producing stable graphene composites to replace current thermal interface materials. Graphene consists of carbon atoms tightly packed in a honeycomb crystal lattice one atom thick which exhibit extremely high thermal conductivity. The new thermal interface material will consist of a mixture of single layer graphene and few-layer graphene flakes which will be utilized by a corporate partner, Amonix Inc. of Seal Beach.

Energy Conservation Research

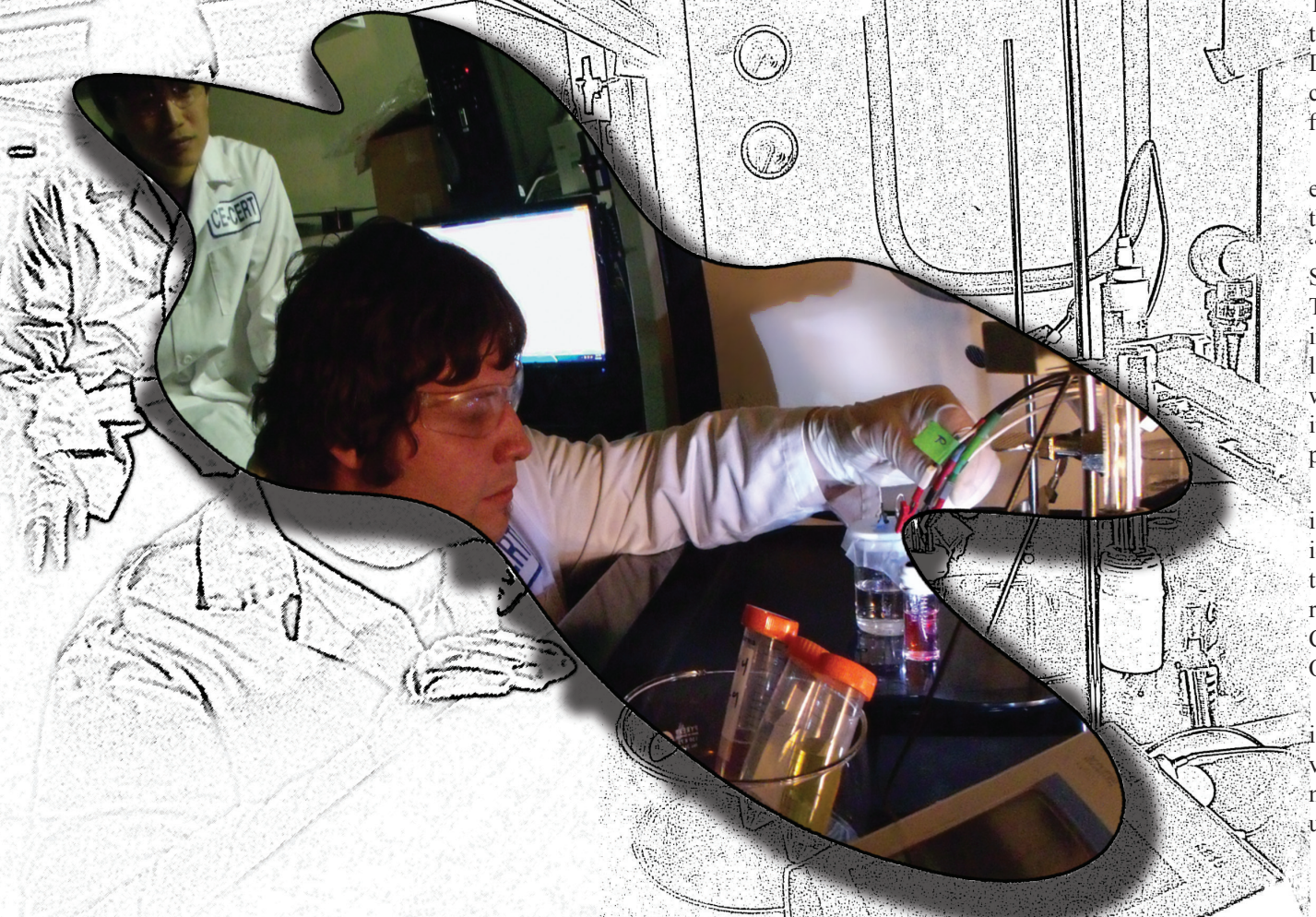
Another important SC-RISE research effort is aimed not at collecting energy but conserving it. The California Energy Commission funded a program to investigate ways to reduce significant energy usage by one of the largest consuming sectors in the state – large electric motors. Nearly one-half of the electricity consumed in California is used by large motors (50 horsepower or larger) to move air (HVAC) and water which are operating 24/7. But for a variety of reasons, these units tend to operate 5-10 percent below their optimum efficiency. For example, to minimize the chance of failure, commercial buildings tend to use larger capacity motors than needed, leading to continuous under-efficiency in operation. Secondly, the relatively low cost differential between different capacity motors and high- versus low-efficiency motors means little thought is given to proper efficiency sizing. Software used by architectural and engineering firms inflates safety factors in calculating motor sizes for buildings, leading to oversized motors being installed in many applications. Finally, a third reason for less than optimum efficiencies is that repairing damaged motors usually results in lower efficiency operation.

Sadrul Ula, has been awarded a grant from the California Energy Commission to conduct the first survey to document the efficiency of existing motors in buildings under actual operating conditions. Though December 2012, CE-CERT will build a baseline data inventory of large HVAC motor energy use in California buildings. The inventory will include motor size, partial loading data, highly resolved temporal data as well as seasonal variations. On-site measurements will begin on CE-CERT's own facilities, university buildings and area government installations. The research will also account for climatic differences in cities across California to provide the Energy Commission a complete picture of potential energy savings statewide.

SC-RISE was also engaged by the Imperial Irrigation District to study the feasibility of a utility-scale solar energy facility on banks of the Salton Sea. Evaporation has caused a chronic shrinking of the Salton Sea, revealing large salt flats with potentially few uses and minimal environmental impacts for solar generation installations. The feasibility study will consider environmental, air quality and technological issues affecting a solar plant on the site. The work will also identify stakeholders, potential partners and funding sources for the construction of a pilot demonstration project. A large exposed lakebed is expected to create air quality problems in its vicinity. This study will also develop an experimental and testing protocol for determining how a large scale solar installation might mitigate air quality issues.

The Imperial County Irrigation District selected SC-RISE to evaluate the feasibility of a utility-scale solar energy facility on the banks of the Salton Sea. The barren salt flats are quite uninhabitable, making the location ideal for solar generation.

2011 Highlights



BCOE Team Wins Connected Vehicle Technology Challenge

A team from the Bourns College of Engineering CE-CERT was named one of six winners of the U.S. Department of Transportation's Connected Vehicle Technology Challenge in 2011.

Rapidly improving wireless technology today offers the ability for vehicles of all types to connect with each other and with traffic signals and mobile devices. The Connected Vehicle Challenge is gathering ideas to utilize an advanced wireless technology standard, Dedicated Short Range Communications (DSRC). The convergence promises a new era of safer and more efficient transportation.

Senior Development Engineer Michael Todd and electrical engineering professors Jay Farrell and Matthew Barth won the award for their competition entry, "Using Dedicated Short-Range Communications Signals for Improving Vehicle Position Estimates." Their entry, a position-estimating system that blends inputs from Global Positioning System and DSRC links to roadways to improve location measurements, was evaluated for its technical and operational feasibility, promise for widespread adoption, innovation, and potential social benefit.

DOT's Research and Innovative Technology Administration sponsored the nationwide competition seeking ideas for using wireless technology to enable vehicles to communicate with each other. Todd presented the research during a special session at the 2011 World Congress on Intelligent Transportation Systems in Orlando in October.

DOT's National Highway Traffic Safety Administration said in an October 2010 report that wireless vehicle-to-vehicle and vehicle-to-infrastructure communications can potentially address 81 percent of all unimpaired vehicle crashes.

Three Honored for Distinguished Service

Environmental leaders representing industry, government and academia were recognized March 3 with the 2011 CE-CERT Distinguished Service Awards. The awards were conferred by Center Director Matt Barth and College of Engineering Dean Reza Abbaschian.

Ford Motor Company executive Robert D. Brown (top photo) was honored for a variety of contributions to UCR, including years of service on the Board of Advisors and a memorable Commencement Address for the Bourns College of Engineering. Robert was unable to receive the award in person, having recently been appointed Global Director, Vehicle Homologation and Compliance/Vice President Sustainability Environment and Safety Engineering Ford of Europe. In this role he is responsible for ensuring all Ford cars and trucks meet or exceed environmental and safety requirements in markets where they are sold.

The honoree representing academia was Joseph Norbeck (center photo) retiring W. Ruel Johnson Professor and founding director of CE-CERT. In addition to his work at the Center, he also organized UCR's Environmental Research Institute and served in advisory roles for the California Inspection/Maintenance Review Committee, the Cal/EPA Environmental Technology Partnership Task Force, the Executive Research Advisory Committee of the Society of Automotive Engineers, and the Scientific Review Committee for the South Coast Air Quality Management District.

The late S. Roy Wilson was recognized for his governmental service. He was Riverside County Supervisor for 14 years during which time his support was considered pivotal in the adoption of the Coachella Valley Multiple Species Habitat Conservation Plan. He also served 22 years on the governing board of the South Coast Air Quality Management District (AQMD), 24 years on the Riverside County Transportation Commission and 14 years on the Mojave Desert Air Quality Management District. Barry Wallerstein, executive officer of AQMD (bottom photo) assisted in the presentation, which was made to Roy's widow, Aurora.

Engineers Help Mythbusters Compare Car, Bike Emissions

Is an automobile or a motorcycle the more environmentally responsible vehicle? With the assistance of CE-CERT Research Engineer Kent Johnson (above), MythBusters Adam Savage and Jamie Hyneman tested the "myth" that a motorcycle is a greener and cleaner machine than a car September 28 on the Discovery Channel.

For the MythBusters episode, which has continued to be re-run on the Discovery network, used Johnson's 20 years of emissions and fuels research to compare the emissions from six different vehicles.

Since vehicle engineering has changed so much over the past 30 years, the MythBusters proposed to test one car and one motorcycle built over each of the past three decades. Johnson looked at the pollutant emissions (CO_2, CO, HCs and NO_x) resulting from the operation of all six vehicles.

Johnson and his colleagues at CE-CERT have been among the leaders in advancing the science of vehicle emissions measurement from laboratory testing, to in-use evaluation, to portable emissions measurement systems. Colleagues David Cocker, associate professor of chemical and environmental engineering, and Tom Durbin, director of the Alternative Transportation Fuels Research Center of Excellence, assisted with the data crunching.

CE-CERT has measured the pollution profiles of hundreds of models of cars using dozens of fuel formulations, as well as testing of many off-road vehicles, stationary pollution sources, locomotives, port vehicles, harbor craft, and ocean-going vessels.

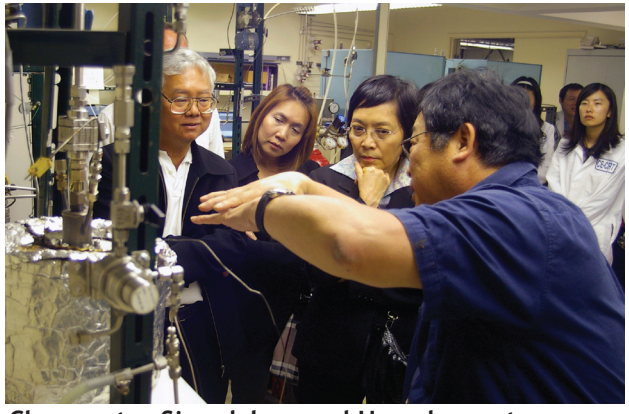
Thai Center Extends Cooperative Research Relationship

Officials of the Thailand Institute of Scientific and Technological Research (TISTR) visited CE-CERT in May. TISTR is an R&D organization of integrated technologies for food, health products, renewable energy, as well as the environment.

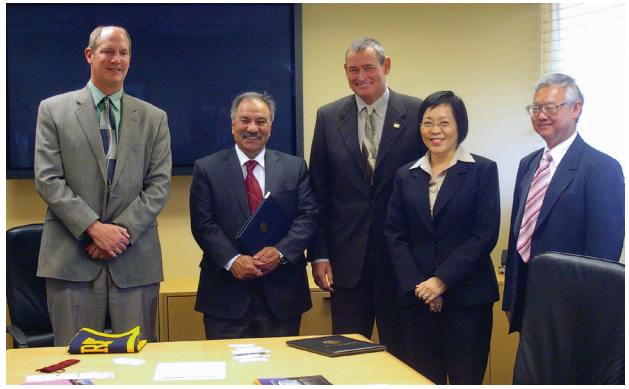
UCR Chancellor Timothy P. White and Governor Homchean signed a Memorandum of Understanding (MOU) which renews and extends an earlier memorandum signed in Thailand. The agreement calls for cooperative research and implementation of UCR's hydrogasification technology for application in Thailand using carbonaceous feedstocks.

Founding Director of CE-CERT, Joseph Norbeck, who has done research in that nation for many years, stimulated Thai interest in the center's patented Steam Hydrogasification Process as a technology well-suited to conditions in Thailand. Since then, TISTR has sponsored a number of graduate students to work in CE-CERT labs.

Two of those students offered presentations on their doctoral research at UCR. Amornrat Suemanotham presented "Microalgae as a Potential Biofuel Feedstock," and Yoothana Thanmongkhon presented "The Production of Synthetic Natural Gas from Biomass."



Chewasatn, Sinoulchan and Homchean, tour the Steam Hydrogasification Lab with Assistant Research Engineer Chan Seung Park.



Participating in the MOU ceremony were (left to right): CE-CERT Director Matt Barth, Bourns College of Engineering Dean Reza Abbaschian, UCR Chancellor Timothy White, TISTR Governor Kasemsri Homchean, and Deputy Governor Sutiporn Chewasatn.

High Performance Computing Boosts Environmental Modeling

CE-CERT has invested in a High Performance Computing (HPC) virtualization server that will provide advanced simulation capabilities for air quality and climate change research. CE-CERT's server combines 12 2.8 Ghz processor cores, 32 GB of RAM and 10 TB of hard disk storage.

The new computing resources provide a significant boost to air quality modeling capability at the Center. Atmospheric simulation is essential for understanding how chemical mechanism models behave under ambient conditions. Modeling is also essential for predicting air quality impacts on projects like the recent multi-agency analysis of controlled burns to clear land on large military bases. The new HPC tools can also be used for projects linking changes in fuels and control technologies to their effects on emissions and air pollutant concentrations.

Bank of America Supports High School Science Outreach

Support from the Bank of America Charitable Foundation will help the College of Engineering-Center for Environmental Research and Technology expand its outreach program—which gives California Science Fair participants the opportunity to work in the laboratory with scientists and engineering mentors.

"As an environmental research and education institution, one of our responsibilities is to promote environmental awareness and a real-world commitment to sustainability," said CERT Director Matt Barth. "We also hope this program plays a part in producing the next generation of environmental researchers."

Participation allowed children of wide socio-economic backgrounds and their teachers the opportunity to see first-hand the cutting edge research at CE-CERT.

Arnie Gonzalez, Javier Vasquez, Pearl Mendoza, Arlene Murillo, representing the Bank of America Charitable Foundation, joined Rebeccah Goldware, BCOE Associate Director of Development, CE-CERT Director Matt Barth and College Dean Reza Abbaschian in a check presentation that continues the Center's effort to support science projects of Riverside Unified School District students.

Historic Gift Brings Promise of Advancements in Energy Storage

The Winston Chung Global Energy Center was established at the Bourns College of Engineering (BCOE) this year through a visionary gift by the Chinese entrepreneur Winston Chung.

CECERT's Sadrul Ula is Managing Director of the center.

The Center's focus is what the National Academy of Engineering identifies as a primary barrier in replacing fossil fuels with solar energy — improving energy storage. The establishment of the WCGEC will further strengthen the connections between the college and CE-CERT.

Collaborating faculty at CE-CERT include Nosang V. Myung, Chair and Professor of Chemical and Environmental Engineering and Faculty Director and Sadrul Ula, Managing Director of the new Center.

Initial research at WCGEC is focusing on innovative material development including graphene-silicon nanostructures, or carbon nanotube/graphene composite based anodes and bio-inspired and electrochemically synthesize cathode materials. Six three-year projects with eight principal investigators representing CE-CERT, the BCOE and UCR faculty were initiated this year:

- Biologically Inspired Cathode Materials
- Nanostructured Electrodes
- Microbatteries from Nanowire Arrays
- Anodes from Graphene/Quantum Dot Composites
- Scalable 3-D Carbon Nanotube-Graphene Nano-Architectures

Atmospheric Inversion Research May Improve Air Regulations

Testing at CE-CERT to measure atmospheric inversions. Inversion layers can concentrate pollutants close to the ground, and accurate predictions of the phenomenon could change the permitting process for distributed electricity generation facilities and other point sources. The work is being conducted by BCOE air pollution dispersion modeling experts Professor Akula Venkatram and Associate Professor Marko Princevac.

Study to Measure Health Risks of Breathing During Daily Commute

Particulate emissions from the burning of transportation fuels is increasingly implicated in human illness and death, but the science of how we are exposed to them and the health effects of breathing these tiny particles still has a long way to go.

Heejung Jung, assistant professor of Mechanical Engineering, has been awarded a UC Transportation Center Faculty Research Grant to 'map' concentrations of particulate matter (PM) along highways.

In 2010, the California Air Resources Board estimated that 9,000 Californians die prematurely each year because of exposure to PM. Often these particles are so small that they can pass directly into the bloodstream.

Jung's research will work to quantify the highest potential exposure, which occurs during the daily commute. Previous studies have already shown that exposure to motorists can be up to 10 times higher than ambient PM concentrations.

Jung will measure the temporal and spatial variations of PM on California highways using mobile instrument platforms installed on two small passenger cars. The team will build its own mobile particle measuring systems and will use telematics developed at the Center for simultaneous measurement of engine parameters and GPS data. The team will also make use of CMEM, the Comprehensive Modal Emissions Model developed at CE-CERT which can predict highway emissions on a second-by-second basis.

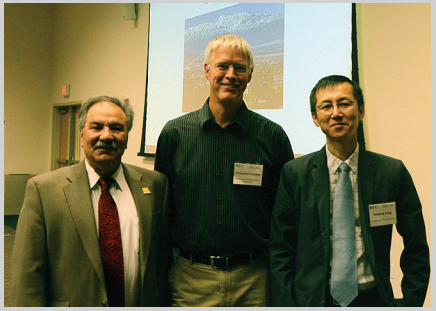
In addition to enhancing the performance of such models, precise understanding of the mechanisms of PM exposure could affect future designs of highways, vehicles and air handling systems, Jung noted.

CE-CERT Welcomes Distinguished Visitors

Jared Blumenfeld (center), administrator for EPA's Pacific Southwest Region, touring CE-CERT with (left to right) Director Matt Barth, UCR Vice Chancellor for Research Charles Louis, and Engineering Dean Reza Abbaschian.

Chinese inventor and businessman Winston Chung (center) toured CE-CERT labs Jan. 24, the same day he announced a record $10 million endowment to support battery technology, solar energy and sustainable transportation research. Chung is accompanied on the tour by (left) Reza Abbaschian, Engineering Dean, (right) Steve Chen, an executive in Chung's organization, and Qing Qing, a UCR alum and post-doc at CE-CERT.

Joel Ayala, Director of the California Office of Economic Development announced the expansion of the San Diego iHub at CE-CERT. The expansion up the I-215 corridor included UCR and Riverside in the successful program to support technology innovation and green job creation. The iHub initiative allows business, academia, government, and venture capitalists to leverage such assets as research parks, technology incubators, universities, and federal laboratories in an effort to foster innovation as a statewide job creation and community building tool.



Heejung Jung hosted the fall meeting of the Western States Section of the Combustion Institute (WSSCI) October 17-18 at UCR. Topics included advancements in chemical kinetics, soot and PAH,and supersonic combustion.

Four Student Researchers Named for Top Research Honors

Center Director Matt Barth announced the winners of the four top fellowship/scholarship awards for 2011. Each of the awards were established by donors to support and encourage research on environmental issues. One of each of the four awards are made by the Center's Awards Committee each year -- two undergraduates and two for graduate students.

The Ford Motor Company Undergraduate Scholarship was awarded to Sarah Bates, a native of England who is a research assistant in the Atmospheric Processes Lab. Her work includes the physical and chemical characterization or re-aerosolized aerosol using a high-resolution time-of-flight aerosol mass spectrometer. She is a member of the UCR chapter of Engineers Without Borders and one of a top academic students in the College of Engineering.

Joseph Dean, winner of the Jim Guthrie Research Award, is a senior in computer science and engineering from Anaheim. He is currently working in the developing smart phone applications which combine CE-CERT's research on Eco-driving and emissions modeling. "I work on bringing practical, environmentally friendly navigation applications to ubiquitously distributed platforms," Dean said. "Presently, I have developed device specific applications for both the iOS and Android operating systems."

The Esther Hays Graduate Fellowship went to Shunuke Nakao of Kawasaki, Japan. Nakao is a graduate student in Chemical and Environmental Engineering who has already authored or co-authored 11 peer-reviewed journal articles.

Nakao investigates chemical mechanisms of secondary organic aerosol (SOA) formation using the CE-CERT environmental chamber. He utilizes state-of-the-art chemical/physical instrumentation including Aerodyne High-Resolution Time-of-Flight Aerosol Mass Spectrometer (HR-ToF-AMS) that provides chemical composition of aerosols in real-time (shown next to him in the picture).

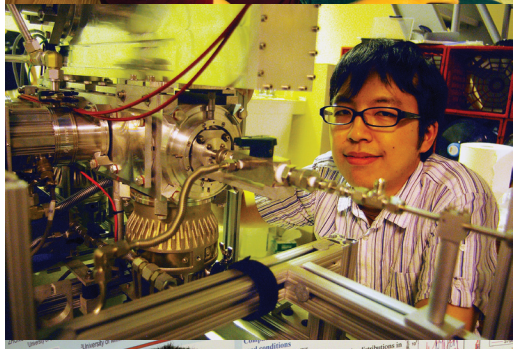
Chinese native Zhongqing Zheng, a graduate student in Mechanical Engineering, received the William R. Pierson/Ford Motor Company Graduate Student Fellowship.

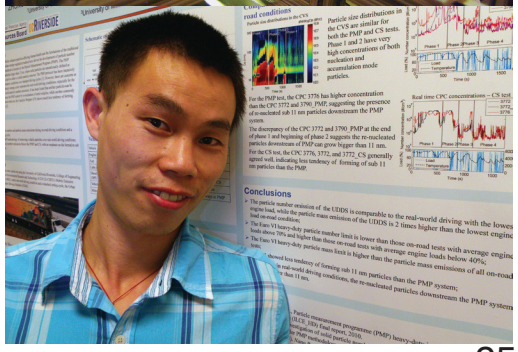
His research focuses on how to better measure particle number (PN) emissions of diesel exhaust nanoparticles, which are harmful to human health. PN regulations for diesel vehicles have been implemented by the European Union to complement the traditional particle mass (PM) regulation method, which suffers from sensitivity problems as regulations become more stringent and emissions are reduced significantly by new technologies.

Zheng investigates some potential drawbacks of the European method and tries to improve it. His research could provide the groundwork for more strict diesel emission regulations in California.

Bates


Dean


Nakao



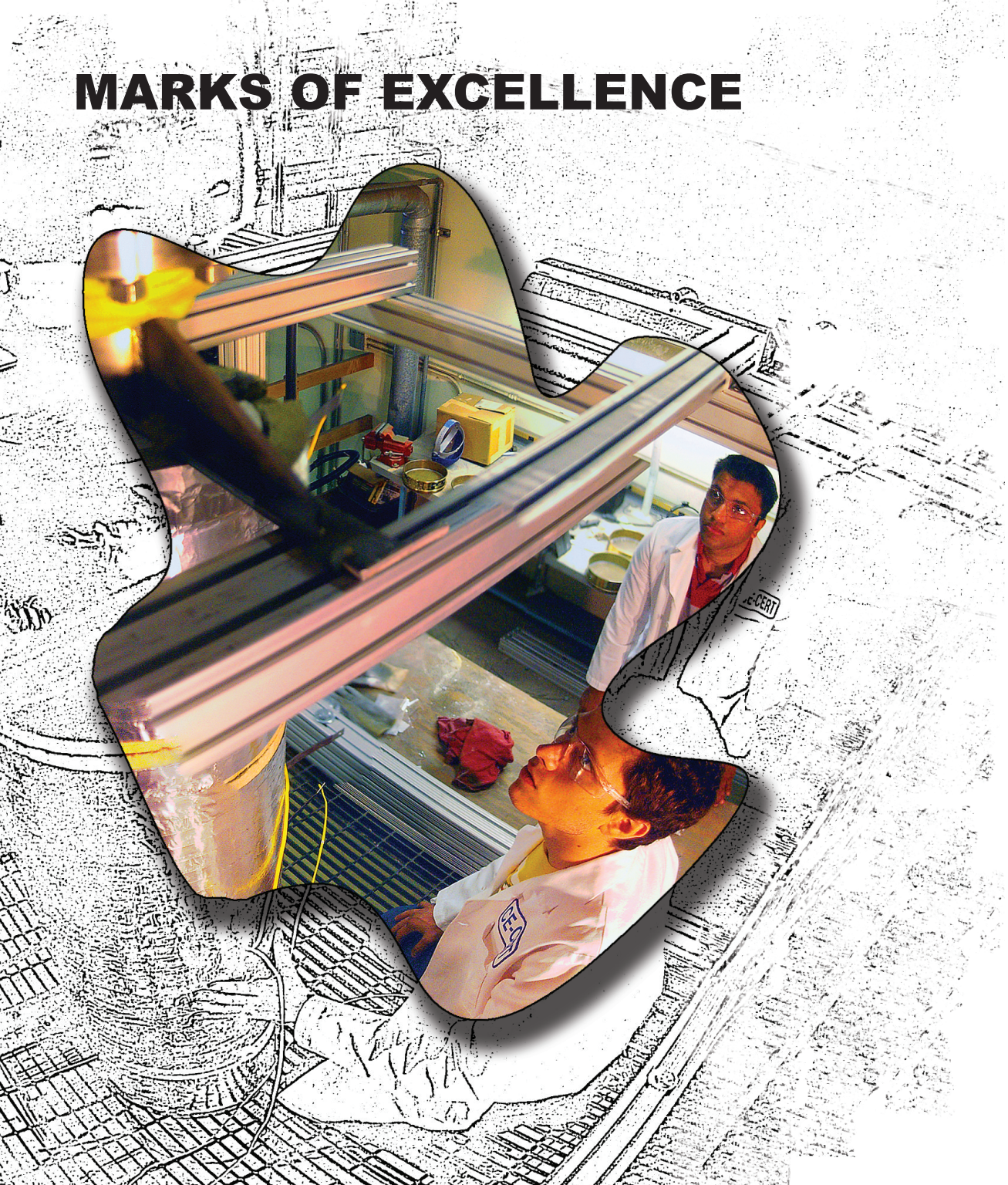
Zheng

Alumna Davis Named CE-CERT Deputy Director

Nicole Davis, a CE-CERT/UCR alumna has returned to the Center as the new Deputy Director, succeeding Dennis Fitz. Ms. Davis received her Master's in Chemical and Environmental Engineering at the University of California, Riverside in 2001, and then served as a research engineer in the Center for Environmental Research and Technology (CE-CERT) until 2004.

In her return to CE-CERT as Deputy Director, her efforts will be focused on both the day to day operations and in fulfilling its mission to serve as a creative source of new technology and a valuable contributor to solving pressing environmental and sustainability issues. She is excited to join the CE-CERT team because she believes that this is a critical time in determining our country's future energy supplies and tackling air quality and climate change challenges.

MARKS OF EXCELLENCE



2011 Journal Publications

Arnott, R., DePalma, E., (2011). “The Corridor Problem: Preliminary Results on the No-toll Equilibrium,” Transportation Research B, 45, 743-768.

Arnott, R., DePalma, E., (2011). “Morning Commute in a Single-Entry Traffic Corridor with No Late Arrivals,” Transportation Research B, 46 (2011), 1-29.

Asa-Awuku, A., Moore, R., Nenes, A., Bahreini, R., Brock, C. A., Middlebrook, A., Holloway , H., Ryerson, T., Jimenez, J., DeCarlo, P., Hecobian, A., Weber, R., Tanner, D., Stickel, R., Huey, L. G. (2011). ‘’Airborne Cloud Condensation Nuclei Measurements during the 2006 Texas Air Quality Study’’ J. Geophys. Res., 116, D11201, doi:10.1029/2010JD014874, 2011

Boriboonsomsin, K., Zhu, W., Li, M., Barth, M., (2011). “A Statistical Approach to Estimating Truck Traffic Speed and Its Application to Emission Inventory Modeling,” in press, Transportation Research Record, 24 pp.

Brethauer, S., Studer, M.H., Yang, B., Wyman, C.E., (2011). “The Effect of Bovine Serum Albumin on Cellulose Hydrolysis under Different Reaction Conditions,” Bioresource Technology, 102 (10) 6295–6298.

Chen, X., Hopke, P., and Carter, W.P.L. (2011). “Secondary Organic Aerosol from Ozonolysis of Biogenic Volatile Organic Compounds: Chamber Studies of Particle and Reactive Oxygen Species Formation,” Environ. Sci. Technol, 2011, 45, 276–282.

DeMartini JD, Pattathil S, Avci U, Szekalski K, Mazumder K, Hahn MG, Wyman CE. (2011). “Application of monoclonal antibodies to investigate plant cell wall deconstruction for biofuels production,” Energy and Environmental Science, 4: 4332-4339.

DeMartini JD, Wyman CE. (2011). “Composition and Hydrothermal Pretreatment and Enzymatic Saccharification Performance of Grasses and Legumes from a Mixed-species Prairie,” Biotechnology for Biofuels, 4 (52); 1-10.

Donohoe, B.S., Vinzant, T.B., Elander, R.T., Pallapolu, V.R., Lee, Y.Y., Garlock, R.J., Balan, V., Dale, B.E., Kim, Y., Mosier, N.S., Ladisch, M.R., Falls, M., Holtzapple, M.T., Rocio, S.R., Shi, J., Ebrik, M.A., Redmond, T., Yang, B., Wyman, C.E., Hames, B., Thomas, S., Warner, R.E., (2011). “Surface and Ultrastructural Characterization of Raw and Pretreated Switchgrass, Bioresource Technology, 102: 11097-11104.

An Evening of Tribute for Joseph Norbeck










Retiring professor and CE-CERT founding director Joseph Norbeck was greeted by about 100 friends and colleagues during a special reception March 2.

Falls, M., Shi, J., Ebrik, M., Redmond, T., Yang, B., Wyman, C.E., Garlock, R.J., Balan, V., Dale, B.E., Pallapolu, V.R., Lee, Y.Y., Kim, Y., Mosier, N.S., Ladisch, M.R., Hames, B., Thomas, S., Donohoe, B.S., Vinzant, T.B., Elander, R.T., Warner, R.E., Rocio, S.R., Holtzapple, M.T., (2011). "Investigation of Enzyme Formulation on Pretreated Switchgrass," Bioresource Technology, 102: 11072-11079.

Garlock, R.J., Balan, V., Dale, B.E., Pallapolu, V.R., Lee, Y.Y., Kim, Y., Mosier, N.S., Ladisch, M.R., Falls, M., Rocio, S.R., Holtzapple, M.T., Shi, J., Ebrik, M.A., Redmond, T., Yang, B., Wyman, C.E., Donohoe, B.S., Vinzant, T.B., Elander, R.T., Hames, B., Thomas, S., Warner, R.E., (2011). "Comparative material balances around pretreatment technologies for the conversion of switchgrass to soluble sugars," Bioresource Technology, 102: 11063-11071.

Hajbabaei, M., Johnson, K., Okamoto, R., Durbin, T., (2011). "Evaluation of the impacts of Biodiesel on Emissions for a California-Certified Diesel Fuel from Heavy-Duty Engines," submitted to Energy and Fuels, September.

Johnson, K., Durbin, T., Jung, H., Cocker, D., Bishnu, D., Giannelli, R., (2011). "Quantifying In-Use PM Measurements for Heavy Duty Diesel Vehicles," Environmental Science and Technology," 45, 6073–6079.

Karavalakis, G., Durbin, T.D., Shrivastava, M., Zheng, Z., Villela, M., Jung, H., (2011). "Impacts of Ethanol Fuel Level on Emissions of Regulated and Unregulated Pollutants from a Fleet of Gasoline Light-Duty Vehicles," Fuel, in press.

Khan, M.Y., Johnson, K.C., Durbin, T.D., Jung, H., Cocker III, D., Bishnu, D., Giannelli. R., (2011). "Characterization of PM-PEMS for In-Use Measurements – Validation Testing for the PM-PEMS Measurement Allowance Program," Atmospheric Environment, September.

Karavalakis, G., Durbin, T.D., Shrivastava, M., Zheng, Z., Villela, M., Jung, H., (2011). Air Pollutant Emissions of Light-duty Vehicles Operating on Various Natural Gas Compositions," Journal of Natural Gas Science & Engineering, in press.

Kim, Y., Mosier, N.S., Ladisch, M.R., Pallapolu, V.R., Lee, Y.Y., Garlock, R.J., Balan, V., Dale, B.E., Donohoe, B.S., Vinzant, T.B., Elander, R.T., Warner, R.E., Falls, M., Rocio, S.R.,

Holtzapple, M.T., Shi, J., Ebrik, M.A., Redmond, T., Yang, B., Wyman, C.E., Warner, R.E.. (2011). "Comparative Study on Enzymatic Digestibility of Switchgrass Varieties and Harvests Processed by Leading Pretreatment Technologies," Bioresource Technology, 102: 11089-11096.

Li, N., Tompsett, G.A., Zhang, T., Shi, J., Wyman, C.E., Huber, G.W., (2011). "Renewable Gasoline from Aqueous Phase Hydrodeoxygenation of Aqueous Sugar Solutions Prepared by Hydrolysis of Maple Wood," Green Chemistry, 13: 91-101.

Lindedam, J., Andersen, S.B., DeMartini, J.D., Bruun, S., Jørgensen, H., Felby, C., Magid, J., Yang, B., Wyman, C.E., (2011). "Cultivar Variation and Selection Potential Relevant to the Production of Cellulosic Ethanol from Wheat Straw," Biomass and Bioenergy, 37: 221-228.

Nakao, S., Shrivastava, M., Nguyen, A., Jung, H., Cocker, D., (2011). "Interpretation of Secondary Organic Aerosol Formation from Diesel Exhaust Photooxidation in an Environment Chamber," Aerosol Science and Technology, 45, 954-962.

Pallapolu, V.R., Lee, Y.Y., Garlock, R.J., Balan, V., Dale, B.E., Kim, Y., Mosier, N.S., Ladisch, M.R., Falls, M., Holtzapple, M.T., Rocio, S.R., Shi, J., Ebrik, M.A., Redmond, T., Yang, B., Wyman, C.E., Donohoe, B.S., Vinzant, T.B., Elander, R.T., Hames, B., Thomas, S., Warner, R.E., (2011). "Effects of enzyme loading and β-glucosidase supplementation on enzymatic hydrolysis of switchgrass processed by leading pretreatment technologies," Bioresource Technology, 102: 11115-11120.

Pisano, J.T., Durbin, T.D., Karavalakis, G., Collins, J., Huai, T., Ayala, A., Cicero-Fernandez, P., Zhang, M., Gutierrez, A., Huo, D., Vo, T., (2011). "Characterization of PM and PM Instruments for High Emitting Light-Duty Gasoline Vehicles," SAE Fuel and Lubricants Conference, Japan, JSAE 20119114, SAE 2011-01-2056.

Pisano, J.T., Muzio, L.J., Durbin, T.D., Gaston, R., Sonnichsen, T., (2011), "Optimization of SNCR NOx Control in a Wood-Fired Boilers," submitted to Combustion Science and Technology, September.

Qing, Q., Wyman, C.E., (2011). "Supplementation with Xylanase and β-xylosidase to Reduce Xylooligomer and Xylan Inhibition of Enzymatic Hydrolysis of Cellulose and Pretreated Corn Stover," Biotechnology for Biofuels, 4 (18); 1-12.

Samuel, R., Foston, M., Jainga, N., Cao, S., Allison, L., Studer, M., Wyman, C.E., Ragauskas, A.J., (2011). "HSQC (heteronuclear single quantum coherence) 13C-1H correlation spectra of whole biomass in perdeuterated pyridinium chloride-DMSO system: An effective tool for evaluating pretreatment," Fuels, 90 (9); 2836-2842.

Shen, J., Wyman, C.E., (2011) "A Novel Mechanism and Kinetic Model to Explain Enhanced Xylose Yields from Dilute Sulfuric Acid Compared to Hydrothermal Pretreatment of Corn Stover," Bioresource Technology, 102: 9111-9120.

Shen, J., Wyman, C.E., (2011). "Application of a Reaction Model to Improve Calculation of the Sugar Recovery Standard for Sugar Analysis," Biotechnology and Bioengineering, 109 (1): 300-305.

Shi, J., Pu, Y., Yang, B., Ragauskas, A., Wyman, C.E., (2011). "Comparison of Microwaves to Fluidized Sand Baths for Heating Tubular Reactors for Hydrothermal and Dilute Acid Batch Pretreatment of Corn Stover," Bioresource Technology, 102 (10) 5952–5961.

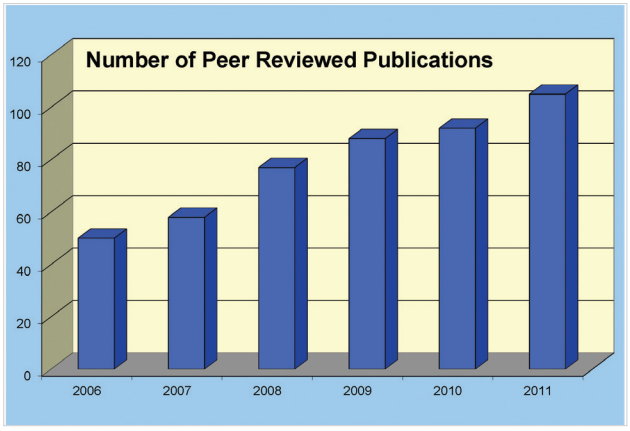
Shi, J., Ebrik, M.A., Wyman, C.E., (2011). "Sugar Yields from Dilute Sulfuric and Sulfur Dioxide Pretreatments and Subsequent Enzymatic Hydrolysis of Switchgrass," Bioresource Technology, 102: 8930-8938.

Shi, J., Ebrik, M., Yang, B., Garlock, R.J., Balan, V., Dale, B.E., Pallapolu, V.R., Lee, Y.Y., Kim, Y., Mosier, N.S., Ladisch, M.R., Holtzapple, M.T., Falls, M., Sierra, R., Donohoe, B.S., Vinzant, T.B., Elander, R.T., Hames, B., Thomas, S., Warner, R.E., Wyman, C., (2011). "Application of Cellulase and Hemicellulase to Pure Xylan, Pure Cellulose, and Switchgrass Solids from Leading Pretreatments," Bioresource Technology, 102: 11080-11088.

Studer, M.H., Brethauer, S., DeMartini, J.D., McKenzie, H., Wyman, C.E., (2011). "Co-Hydrolysis of Dilute Pretreated Populus Slurries to Support Development of a High Throughput Pretreatment System," Biotechnology for Biofuels, 4 (19); 1-10.

Studer, M.H., DeMartini, J.D., Davis, M.F., Sykes, R.W., Davison, B.H., Keller, M., Tuskan, G.A., Wyman, C.E., (2011). "Lignin Content in Natural Populus Variants Affects Sugar Release," Proceedings of the National Academy of Science, in press.

Tao, L., Aden, A., Elander, R.T., Pallapolu, V.R., Lee, Y.Y., Rebecca J. Garlock, R.J. Balan, V., Dale, B.E., Kim, Y., Mosier, N.S., Ladisch, M.R., Falls, M., Holtzapple, M.T., Sierra, R., Shi, J., Ebrik, M.A., Redmond, T., Yang, B., Wyman, C.E., Hames, B., Thomas, S., Warner, R.E., (2010). "Process and Techno-economic Analysis of Leading Pretreatment Technologies for Lignocellulosic Ethanol Production Using Switchgrass," Bioresource Technology, Bioresource Technology, 102: 11105–11114.



Wu, G., Du, Y., Jang, K., Chan, C.-Y., Boriboonsomsin, K., (2011). "Preliminary Evaluation of Operational Performance Between Different Types of HOV Facilities in California: Continuous-access vs. Limited-access," Transportation Research Record, 2229, 93-101.

Wyman, C.E., (2011). "An Introduction to the Special Section on Application of Leading Pretreatments to Switchgrass by the Biomass Refining Consortium for Applied Fundamentals and Innovation (CAFI)," Bioresource Technology 102(24): 11051.

Wyman, C.E., Balan, V., Dale, B.E., Elander, R.T., Falls, M., Hames, B., Holtzapple, M.T., Ladisch, M.R., Lee, Y.Y., Mosier, N., Pallapolu, V.R., Shi, J., Thomas, S.R., Warner, R.E., (2011). "Comparative Data on Effects of Leading Pretreatments and Enzyme Loadings and Formulations on Sugar Yields from Different Switchgrass Sources," Bioresource Technology, 102: 11052-11062.

Yang, B., Dai, Z., Ding, S.Y., Wyman, C.E., (2011)."Enzymatic Hydrolysis of Cellulosic Biomass: A Review," Biofuels, 2(4); 421-450.

Zheng, Z., Durbin, T.D., Karavalakis, G., Johnson, K.C., Chaudhary, A., Cocker III, D.S.,

Herner, J.D., Robertson, W.H., Huai, T., Ayala, A., Kittelson, D.B., Jung, H.S., (2011). "Evaluation of the European PMP Methodologies during On-Road Testing: Focus on Real Time Data Analysis," submitted to Aerosol Science and Technology, September.

Zheng, Z., et al., (2011). "Investigation of Solid Particle Number Measurement: Existence and Nature of Sub 23 nm Particles under PMP Methodology," Journal of Aerosol Science, 42, 883-897.

2011 Books & Book Chapters

Arnott, R., "Parking Economics", Chapter 31 in A. de Palma, R. Lindsey, E. Quinet, and R. Vickerman, eds., Handbook in Transport Economics (2011) Edward Elgar: Cheltenham, UK.
Arnott, R., "What Planners Need to Know about the 'New Urban Economics'," in N. Brooks, K. Donaghy, ad G. Knapp, eds. The [Oxford] Handbook of Urban Economics and Planning (2011) Oxford University Press: Oxford, UK.

2011 Peer-Reviewed Conference Proceedings

Barth, M., Mandava, S., Boriboonsomsin, K., Xia, H., (2011). "Dynamic Eco-driving for Arterial Corridors", Proceedings of the IEEE Forum of Integrated Sustainable Transportation, Vienna Austria, June, 7 pp.

Biswas, S., Robertson, W.H., Na, K., Ladzinski, T., Durbin, T.D., Okamoto, R., Sahay, K., Lemieux, S., (2011). "Real-Time Particulate Matter Emissions from Heavy-Duty Vehicles Tested on Different Biodiesel Blends," 21st CRC Real World Emissions Workshop, San Diego, CA, March.

Boriboonsomsin, K., Barth, M., Vu, A. (2011). "Evaluation of Driving Behavior and Attitude towards Eco-driving: A Southern California Case Study," Proceedings of the 90th Transportation Research Board Annual Conference, Washington, DC, January, 14 pp.

Boriboonsomsin, K., Wu, G., Scora, G., Barth, M., (2011). "Impacts of Goods Movement Pricing on Traffic Congestion and Air Pollution: A Case Study of the Ports of Los Angeles and Long Beach," Proceedings of the Transportation Research Forum, Long Beach, CA, March, 10 pp.

Boriboonsomsin, K., Zhu, W., Barth, M., (2011). "A Statistical Approach to Estimating Truck Traffic Speed and Its Application to Emission Inventory Modeling," Proceedings of the 90th Transportation Research Board Annual Conference, National Research Council, Washington, DC, January, 16 pp.

Cao M., Barth, M., (2011). "Mobile Traffic Surveillance System for Dynamic Roadway and Vehicle Traffic Data Integration," Proceedings of the IEEE Intelligent Transportation Systems Conference, Washington D.C., October, 7 pp.

DeMartini, J.D., Selig, M.J., Tucker, M.P., Turner, G., Studer, M.H., Himmel, M.E., Decker, S.R., Wyman, C.E., (2011). "High-Throughput Compositional Analysis of Lignocellulosic Biomass," Genomic Sciences Contractor-Grantee Meeting/USDA-DOE Plant Feedstock Genomics for Bioenergy Awardees Meeting, Arlington, VA, April 11.

DeMartini, J.D., Pattathil, S., Avci, U., Foston, M., Sannigrahi, P., Sekalsky, K., Mazumder, K., Ragauskas, A.J., Hahn, M.G., Wyman, C.E., (2011). "Monitoring the Effect of Hydrothermal Pretreatment on the Chemistry and Structure of Populus Trichocarpa to Identify Characteristics that Affect Digestibility," Gordon Conference on Cellulosomes, Cellulases, and Other Carbohydrate Binding Enzymes, Stonehill College, MA, July, 25.

DeMartini, J.D., Pattathil, S., Avci, U., Foston, M., Sekalsky, K., Mazumder, K., Ragauskas, A.J., Hahn, M.G., Wyman, C.E., (2011). "Monitoring the Effect of Hydrothermal Pretreatment on the Chemistry and Structure of Populus Trichocarpa to Identify Characteristics that Affect Digestibility," 33rd Symposium on Biotechnology for Fuels and Chemicals, Seattle, WA, May.

DeMartini, J.D., Wyman, C.E., (2011). "Examining spatial effects of steam pretreatment on the digestibility of wood chips: does chip size limit the effectiveness of pretreatment?" 5th BioEnergy Science Center Annual Retreat, Chattanooga, TN, July 18.

Durbin, T.D., (2011). "Alternative Transportation Fuel Research at the University of California at Riverside and Building the California Roadmap to the Future," Imagining the Future Lecture Series, Palm Desert, California, January.

Durbin, T.D., (2011). "UC Riverside Research in Alternative Fuels for Transportation Applications. Sustainable Mobility & Cities: Marrying Technology & Policy," Berkeley, California, February.

Durbin, T.D., (2011). "Studies of N_2O Emissions from Motor Vehicles at the University of California at Riverside," 5th Expert Meeting on Data for the IPCC Emission Factor Database (EFDB), Mumbai, India, October.

Durbin, T.D., Karavalakis, G., Bumiller, K., Villela M., Miller. J.W., (2011). "Effects of Olefins Content on Exhaust Emissions: CRC Project E-83," 21st CRC Real World Emissions Workshop, San Diego, CA, March.

Durbin, T.D., Robertson, W., Okamoto, B., Hajbabaei, M., Johnson, K., Na, K., Miller, J.W., Biswas, S., Ladzinski, T., Gatt, G., Sahay, K., (2011). "Comprehensive assessment of the emissions from the use of biodiesel in California," 2011 Fall Technical Meeting of the Western States Section of the Combustion Institute, Riverside, CA, October.

Durbin, T.D., Karavalakis, G., Norbeck, J., Hajbabaei, M., Miller, J.W., (2011). "Development of CE-CERT's Alternative Transportation Fuels Research Center of Excellence," 21st CRC Real World Emissions Workshop, San Diego, CA, March.

Durbin, T.D., Karavalakis, G., Johnson, K.C., Bumiller, K., Villela, M., and Miller. J.W., (2011). "Effect of Natural Gas Fuel Composition on Vehicle Emissions and Performance," 21st CRC Real World Emissions Workshop, San Diego, CA, March.

Fan, X., Park, C.S., Norbeck, J.M., (2011). "Effect of Reaction Conditions on Steam Hydrogasification in Inverted Batch Reactor," ACS National Meeting, Anaheim, CA, March 2011.

Gao, X, Kumar, R., Wyman, C.E., (2011). "Performance and Characterization of BRC Pretreatments Applied to Corn Stover," 5th BESC Retreat, Chattanooga, TN, July 18.

Gao, X., Li, H., DeMartini, J.D., Wyman, C.E., (2011). "Development and Application of a High Throughput System to Investigate the Effects of Thermochemical Pretreatment and Enzymatic Hydrolysis of Cellulosic Biomass," 241st ACS Annual Meeting, Anaheim, California, March 31, 2011

Gao, X., Wyman, C.E., (2011). "Progress and Plans for Comparison of Enzymatic Hydrolysis of Biomass from Different Pretreatments -- A Joint Project of JBEI, GLBRC and BESC," BESC Characterization Workshop, Golden, Colorado, January.

Gao, X., Wyman, C.E., (2011). "Application of a High Throughput System to Investigate the Effects of Two Stage Pretreatment Strategy on Enzymatic Hydrolysis of Cellulosic Biomass," 33rd Symposium on Biotechnology for Fuels and Chemicals, Seattle, WA, May 2-5.

Hajbabaei, M., Durbin, T.D., Johnson, K., Miller, J.W., (2011). "Assessment of the Emissions from the Use of California Air Resources Board Qualified Diesel Fuels in Comparison with Federal Diesel Fuels," 2011 Fall Technical Meeting of the Western States Section of the Combustion Institute, Riverside, CA, October.

He, W., Park, C.S., Norbeck, J.M., (2011). "Hydrothermal Treatment of Comingled Wood Wastes and Biosolids: Carbon Distribution in Products," ACS National Meeting, Anaheim, CA, March.

He, W., Park, C.S., Norbeck, J.M., (2011). "Lab Scale and Pilot Demonstration Scale Study of Hydrothermal Pretreatment of Wood Wastes and Biosolids," ACS National Meeting, Anaheim, CA, March 2011.

Heo, G. (2011). "Air Pollution: Developing and Using Chemical Mechanisms to Solve Air Pollution Problems," 21st Korean-American Scientists and Engineers Association South-Western Technology Conference, Norwalk, CA, February.

Heo, G., Nakao, S., Cocker, D.R., Carter, W.P.L., (2011). "UCR's experimental database to develop and evaluate atmospheric mechanisms of O3 and SOA formation," 28th Informal Symposium on Kinetics and Photochemical Processes in the Atmosphere, UC Irvine, CA, March.

Heo, G., Nakao, S., Tang, P., Cocker, D., William, P.L.C., (2011). "Development and evaluation of PM-SAPRC to model secondary organic aerosol formation from various aromatic compounds," 30th Annual Conference of the American Association for Aerosol Research, Orlando, FL, October.

Huan, L., Barth, M., (2011). "An Analysis of U.S. EPA'S MOVES Model's Operating Modes and Handling of History Effects," Proceedings of the 90th Transportation Research Board Annual Conference, National Research Council, Washington, DC, January, 17 pp.

Jin,Y., Shi, J., Kumar, R., Wyman, C.E., (2011). "Performance Comparison of Various Ethanologenic Microbes for SSF and SSCF of Pure Sugars and Cellulosic Biomass," 33rd Symposium on Biotechnology for Fuels and Chemicals, Seattle, WA, May 2-5.

Jin, Y.,Shi J, Kumar, R., Wyman, C.E., (2011). "Performance Comparison of Various Ethanologenic Microbes for SSF and SSCF of Pure Sugars and Cellulosic Biomass," 241st ACS Annual Meeting, Anaheim, California, March 31.

Johnson, K.C., Durbin, T.D., Jung, H., Cocker III, D.R., (2011). "Final Summary of PM Measurement Comparisons with UCR's MEL for In-use Testing of Heavy Duty Diesel Vehicles," 2011 Fall Technical Meeting of the Western States Section of the Combustion Institute, Riverside, CA, October.

Johnson, K.C., Miller, J.W., Durbin T.D., (2011)."High NH3 Emissions from In-Use LNG Heavy-Duty Vehicles: Comparison between Diesel and Low NOx LNG," 21st CRC Real World Emissions Workshop, San Diego, CA, March.

Johnson, K., Durbin, T., Miller, J.W., (2011). "Emissions from In-Use NG, Propane, and Diesel Fueled Heavy Duty Vehicles," 2011 Directions in Engine-Efficiency and Emissions Research (DEER), Detroit, MI, October.

Johnson, K.C., Durbin, T.D., Jung, H., Cocker III, D.R., (2011). "Final Summary of PM Measurement comparisons with UCR's MEL for in-use testing of heavy duty diesel vehicles," 21st CRC Real World Emissions Workshop, San Diego, CA, March.

Jung, H., Zheng, Z., Johnson, K.C., Liu, Z., Durbin, T.D., Kittelson, D.B., Hu, S., Huai, T., (2011). "Measurement of Diesel Solid Nanoparticle Emissions Using a Catalytic Stripper for Comparison with Europe's PMP Protocol," 2011 Directions in Engine-Efficiency and Emissions Research (DEER), Detroit, MI, October.

Kumar, N., Dabdub, D., Heo, G., Knipping, E., Luecken, D., Mathur, R., McKeen, S., Pleim, J., Yarwood, G., (2011). "Summary of EPRI-AWMA Workshop on Future Air Quality Model Development Needs," 10th Annual CMAS Conference, Chapel Hill, NC, October.

Kumar, R., Hubbell, C.A., Ragauskas, A., Wyman, C.E., (2011). "Comparison of Laboratory Delignification Methods, Their Selectivity, and Impacts on Physiochemical Characteristics of Cellulosic Biomass," 241st ACS Annual Meeting, Anaheim, California, March 31.

Li, H., Wyman, C.E., (2011). "Application of High Throughput System to Assess Agave as a Biofuels Feedstock for Semi-Arid Lands," 241st ACS Annual Meeting, Anaheim, California, March 31

Li, H., Wyman, C.E., (2011)."Application of High Throughput Systems to Assess Agave as a Low Lignin Biofuels Feedstock for Semi-Arid Lands," 5th BESC Retreat, Chattanooga, TN, July 18.

Li, H., Qing, Q., Wyman, C.E., (2011). "Development of An Improved Analytical Method to Characterization DP Distribution of Xylooligosaccharides Produced by Biomass Pretreatment," CE-CERT Board of Advisors Meeting, Riverside, California, March 3.

Li, H., Wyman, C.E., (2011). "Application of High Throughput System to Access Agave as a Biofuels Feedstock for Semi-Arid Lands," 33rd Symposium on Biotechnology for Fuels and Chemicals, Seattle, WA, May 2-5.

Li, H., Gao, X., Wyman, C.E., (2011). “Development of Dilute Alkali and Dilute Acid Pretreatment and Co-Hydrolysis High Throughput Systems,” BESC Characterization Workshop, Golden, Colorado, January 6.

Liu, Z., Park, C.S., Norbeck, J.M., (2011). “Investigation of Sorption Enhanced Steam Hydrogasification of Coal for In-Situ Removal of CO2 and Self-Sustained Hydrogen Supply,” 2011 International Pittsburgh Coal Conference September, 2011.

McKenzie, H.L., Engle, N., Foston, M., Tschaplinski, T., Ragauskas, A., Wyman, C.E., (2011). “Characterization of Lignin after Water-only Pretreatment,” 5th BESC Retreat, Chattanooga, TN, July.

McKenzie, H.L., Engle, N.L., Foston, M.B., Ragauskas, A., Tschaplinski, T., Wyman, C.E., (2011), “Characterization of Lignin After Water-Only Pretreatment,” 33rd Symposium on Biotechnology for Fuels and Chemicals, Seattle, WA, May.

Na, K., Robertson, W.H., Biswas, S., Ladzinski, T., Durbin, T., Okamoto, R., Sahay, K., Lemieux, S., (2011). “A Comparative Study of Four Heavy-Duty Diesel Trucks Equipped with Different Exhaust Aftertreatment Devices Using Various Biodiesel Blend Levels,” 21st CRC Real World Emissions Workshop, San Diego, CA, March.

Pisano, J.T., Muzio, L., Karavalakis, G., Durbin, T.D., Sonnichsen, T., (2011). “Optimization of Combustion and NH3 Slip from Selective (Non-) Catalytic Reduction Systems in Wood-fired Industrial Boilers,” 2011 Fall Technical Meeting of the Western States Section of the Combustion Institute, Riverside, CA, October.

Scora, G., Morris, B., Tran, C., Barth, M., Trivedi, M., (2011). “Real-Time Roadway Emissions Estimation using Visual Traffic Measurements,” Proceedings of the IEEE Forum of Integrated Sustainable Transportation, Vienna, Austria, June, 7 pp.

Sun, X., Zhang, T., Zhang, B., Wyman, C.E., (2011).”Fermentation of Dilute Organic Acid and Mineral Acid Pretreated Maplewood Liquor by Engineered Escherichia coli K011,” 241st ACS Annual Meeting, Anaheim, California, March 31.

Tadi, T., Boriboonsomsin, K., Barth, M., (2011). “Role of High Occupancy Vehicle (HOV) Lanes in Combating Congestion and Emissions – California Case Study,” Proceedings of Conference of Transportation Research Group of India (CTRG), Bangalore, India, December, 12 pp.

Truong, T., Yen, T.S., Wong, T., Cicero-Fernandez, P., Jim Guthrie, J., Okamoto, R., Ron Walter, R., Mitchell, A., Dzhema, I.,

Huo, D., Ling, R., Rieger, P., Fuentes, M., Durbin, T.D., (2011). “Comparison of Tailpipe Emissions Between Low Carbon Fuel Biodiesel Blends Versus California Diesel on Transportation Refrigeration Units,” 21st CRC Real World Emissions Workshop, San Diego, CA, March.

Vu, A., Farrell, J., Barth, M., (2011). “Robust Landmark Surveying Using an Integrated Camera, Carrier-Phase DGPS, and Inertial Navigation System,” Proceedings of the Institute of Navigation GNSS 2011 Conference, Portland, OR, September, 10 pp.

Wu, G., Du, Y., Jang, K., Chan, C.-Y., Boriboonsomsin, K., (2011). “Preliminary Evaluation of Operational Performance Between Different Types of HOV Facilities in California: Continuous-access vs. Limited-access,” Proceedings of the 90th Annual Meeting of the Transportation Research Board, Washington, DC, January 23-27.

Wyman, C.E., Gao, X., Uppugundla, N., de Costa Sousa, L., Chundawat, S., Dale, B.E., Balan, V., Singh, S., Varanasi, P., Dibble, D., Cheng, G., Simmons, B., Donohue, T., Keasling, J., Glina, P., (2011). “BRC Collaboration to Characterize Structure and Sugar Yields from Three Different Pretreatment of Corn Stover,” Genomic Sciences Contractor-Grantee Meeting/USDA-DOE Plant Feedstock Genomics for Bioenergy Awardees Meeting, Arlington, VA, April 11.

Xia, H., Boriboonsomsin, K., Barth, M., (2011). “Indirect Network-wide Energy/Emissions Benefits from Dynamic Eco-driving on Signalized Corridors,” Proceedings of the IEEE Intelligent Transportation Systems Conference, Washington D.C., October, 6 pp.

Yang, Q., Boriboonsomsin, K., Barth, M., (2011). “Arterial Roadway Energy/Emissions Estimation using Modal-Based Trajectory Reconstruction,” Proceedings of the IEEE Intelligent Transportation Systems Conference, Washington D.C., October, 6 pp.

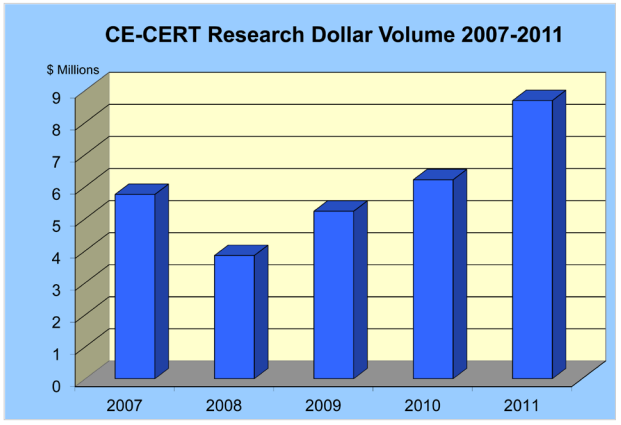
Zhang, T., Kumar, R., Wyman, C.E., (2011). “Enhanced Furfural Production from Cellulosic Biomass by Simultaneous Solvent Extraction Followed by Conversion of the Cellulose Enriched Solids to Glucose,5-(Hydroxymethyl) Furfural, and Levulinic Acid,” 33rd Symposium on Biotechnology for Fuels and Chemicals, Seattle, WA, May, 2.

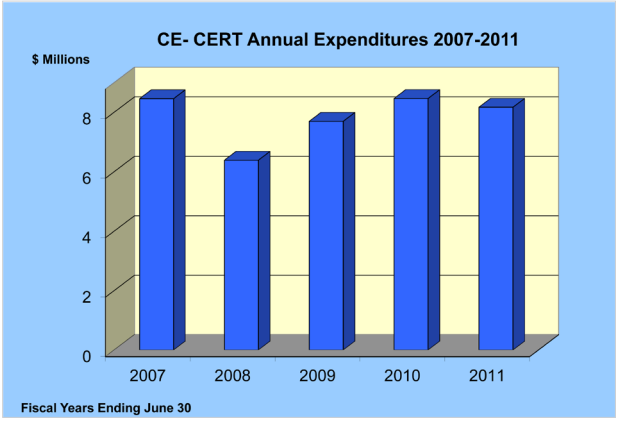
Zhang, T., Qing, Q, Kumar, R., Wyman, C.E., (2011).”Kinetics Study of Furfural Production From Cellulosic Biomass,”AIChE Annual Meeting, Minneapolis, MN, Oct 18.

Zhang, T., Wyman, C.E., (2011). “Integrated Production of Levulinic Acid and Furfural from Cellulosic Biomass”, 241st ACS Annual Meeting, Anaheim, California, March 31.

Zhang, T., Wyman, C.E., (2011). “Comparison and Optimization of Hemicellulose Extraction from Maple Wood by Different Acid Pretreatments ,” 241st ACS Annual Meeting, Anaheim, California, March 31.

CE-CERT Financial Indicators





In 2011, CE-CERT entered into research contracts totaling $8.6 million, showing a substantial growth in research income of 40 percent over the previous year. Expenditures have remained relatively constant over the past three years.

Contracts & Grants Awarded in 2011

Abbaschian, Reza. Terrafore, Inc. “Using Encapsulated Phase Change Material for Thermal Energy Storage for Baseload Concentrating Solar Power Plants.”

Asa-Awuku, Akua. Environmental Protection Agency (EPA). “Understanding the Hygroscopic Properties Of Black Carbon/ Organic Carbon Mixing States: Connecting Climate And Health Impacts Of Anthropogenic Aerosol”

Barth, Matthew. UC Los Angeles, National Science Foundation (NSF). “NETS: Collaborative Research: Closing the Loop Between Traffic / Pollution Sensing and Vehicle Route Control Using Traffic Lights and Navigators.”

Barth, Matthew. Gem Power, LLC. “Phase 2: Electronics Evaluation for Aircraft Battery SOC and Integrity Estimation.”

Barth, Matthew. UC Berkeley, Department of Transportation. “Engaging the International Community: Research on Intelligent Transportation Systems (ITS) Applications to Improve Environmental Performance.”

Barth, Matthew. Vision Motor Corporation. “Heavy Duty Fuel Cell Vehicle CAN Bus Development.”

Barth, Matthew. Nissan Motor Company. “Research, Development, and Evaluation of ECO-ITS Technology to Support Off-Cycle CO2 Reductions.”

Barth, Matthew. UC Berkeley, UCTC. “ECO-ITS Program Support.”

Barth, Matthew. UC Berkeley, UCTC. “ECO-Friendly Navigation System Research for Heavy-Duty Trucks.”

Barth, Matthew. California Air Resources Board. “ARB EMFAC Redesign Review.”

Barth, Matthew. Department of Energy (DOE). “Next Generation Environmentally Friendly Driving Feedback Systems Research and Development.”

Boriboonsomsin, Kanok. Calmar Telematics. “Real-Time Energy/Emission Estimation and Management System for Heavy-Duty Trucks.”

Boriboonsomsin, Kanok. UC Berkeley, UCTC. “Development and Evaluation of Intelligent Energy Management Strategies for Plug-in Hybrid Electric Vehicles.”

Carter, William. University of Texas – Austin, Texas Air Center. “Implementation of Modified Carbon Bond Mechanisms in CAMx.”

Durbin, Tom. California Air Resources Board. “CARB Biodiesel Certification Testing.”

Durbin, Tom. Electric Power Research Institute. “Testing TDL Instrument for Measurement of HCl and HF.”

Durbin, Tom. California Air Resources Board. “Construction of a Low-Level SO_2 DOAS for Installation at a CARB Emissions Testing Facility.”

Fitz, Dennis. South Coast Air Quality Management District. “Evaluation of a Protocol for Measuring VOC Emissions from Cleaning Paint Brushes with Solvent.”

Johnson, Kent. California Air Resources Board. “Air Quality Improvement Program (AQIP): Hybrid Deployment and Testing Evaluation.”

Johnson, Kent. Southern California Ship Services. “Measurement of the Effectiveness of Containment Hoods.”

Johnson, Kent. Emisense Technologies. “Analysis and Testing of the EmiSense Electronic PM Sensor on Various Heavy Duty Diesel Vehicles.”

Johnson, Kent. California Air Resources Board. “Development of a Portable In-Use Reference PM Measurement System.”

Jung, Heejung. UC Berkeley, UCTC. “Temporal and Spatial Variations of Particulate Emissions on Major Highways: Lagrangian Approach Using Mobile Monitoring System.”

Jung, Heejung. Fossil Energy Research Corporation. “Control Strategies and Technologies for Particulate Matter Under 2.5 Microns (PM2.5) and Ultrafine Particulate Emissions from Natural Gas-Fired Gas Turbine Power Plants.”

Karavalakis, Georgios. Calumet Specialty Products Partners. “Evaluation of Regulated and Toxic Emissions from Two-Stroke Utility Engines.”

Miller, J. Wayne. FOSS Maritime Company. “Development of Emission Factors for Foss Tug Boat for EPA Verification.”

Miller, J. Wayne. South Coast Air Quality Management District. “In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy-Duty Engines.”

Miller, J. Wayne. California Air Resources Board. “Emission Testing of Port Engines and Other Sources of Diesel Particulate Matter.”

Miller, J. Wayne. California Energy Resources and Conservation Development Commission. “Evaluation and Improvement of Particulate Matter Measurement from NG Power Plants.”

Norbeck, Joseph. California Energy Resources and Conservation Development Commission. “Production of Substituted Natural Gas from the Wet Organic Waste by utilizing PDU-scale Steam Hydrogasification Process.”

Norbeck, Joseph. California Institute for Energy and Environment. “Life Cycle Analysis of Algae Biofuels.”

Park, Chan Seung. University of California. “University of California Discovery Grant.”

Park, Chan Seung. Power Waste Gasification, LLC. “Proposal to Evaluate a Waste-To-Energy Gasification Process.”

Park, Chan Seung. Cornerstone Technology Partners, Inc. “Process Integration of Hydrothermolytic Decomposition and Steam Hydrogasification in Producing Biofuel from Biowastes”

Russell, Robert. International Sustainable Systems Research Center. “Evaluation of Air Pollutant Emissions and Fuel Economy of Liquefied Petroleum Gas (LPG) Powered Buses/Trucks.”

Russell, Robert. Department of Transportation Maritime Administration. “Emissions Testing on Board the Great Lakes Merchant marine Academy Vessel: State of Michigan.”

Ula, Sadrul. UC California Institute for Energy and Environment. “Evaluation of Energy Efficient HVAC Electric Motor Systems in Buildings Based on On-site and Off-site Measurements and Testing.”

Wyman, Charles. Oakridge National Laboratory. “Biomass Characterization Pretreatment Research.”

Wyman, Charles. Menon and Associates, Inc. “Process Improvements in Pretreatments to Improve Final Yields of Biofuel Production Through Biological Conversions.”

Wyman, Charles. National Renewable Energy Laboratory. “Characterization and Conversion of Xylooligomers Released During Hydrothermal (HT) and Low Severity Dilute Acid (LSDA) Pretreatments.”

Wyman, Charles. Logos Technologies, Inc. “Phase II: Production of Sugars and Conversion to TAG.”

Wyman, Charles. Oregon State University. “Enhanced Production of Reactive Intermediates from Cellulosic Biomass for Aqueous-Phase Catalytic Processing to Drop-In Fuels.”

Scholarship and Award Winners

Sarah Bates, Ford Undergraduate Scholarship
Joseph Dean, Jim Gutherie Scholarship
Corey Hardin, Lung-Wen Tsai Memorial Award for Research in Mechanical Design
Rajeev Kumar, Assistant Research Engineer, "Outstanding Reviewer Award" from the Journal of Bioresource Technology, Elsevier Ltd., Oxford.
Shunsuke Nakao, Esther Hayes Graduate Fellowship
Zhongqing Zheng, Ford Pierson Graduate Fellowship
Seyed A. Hashemi, College Cost Reduction and Access Act (CCRAA) Grant
Daniela Gutierrez, CCRAA Grant
Erika Aragon, CCRAA Grant
Andrew Matsumoto, CCRAA Grant
Sasan Mojgani, CCRAA Grant
Nicholas Jarak, CCRAA Grant
Eduardo Cuevas, CCRAA Grant
Joshua Dolson, Research Advancement Program (RAP)
Taehoon Lim, Dean's Distinguished Fellowship

Ph.D. Graduates (dissertation title)

Jaclyn DeMartini, Ph.D., "Chemical and Structural Features of Plants That Contribute to Biomass Recalcitrance."
Wei He, Ph.D., "The Development of a Hydrothermal Method for Slurry Feedstock Preparation for Gasification Technologies."
George Scora, Ph.D. "Heavy Duty Diesel Particulate Matter and Fuel Consumption Modeling for Transportation Analysis."
Anh Vu, Ph.D. "Robust Vehicle Segmentation and Tracking from Monocular Videos for Improved Traffic Sensing and Management"

Master's Graduates (thesis title)

Elijah DePalma, "Sequential Hypothesis Testing With Spatially Correlated Presence-Absence Data and the Corridor Problem" (2011).
Waner Gu, "Essays on Foreign Direct Investment, Growth and the Environment" (2011).
Corey Hardin, "Phase Change Materials for Thermal Energy Storage in Concentrated Solar Thermal Power Plants."
Danqing Hu, "Essays on Dynamic Congestion Games" (2011).

Faculty

Richard Arnott, Professor of Economics
Akua Asa-Awuku, Assistant Professor of Chemical and Environmental Engineering
Matthew Barth, CE-CERT Director and Professor of Electrical Engineering
Kanok Boriboonsomsin, Research Faculty, Intelligent Transportation Systems
David Cocker, Professor of Chemical and Environmental Engineering
William Carter, Research Faculty, Atmospheric Chamber
Thomas Durbin, Research Faculty, Emissions Engines and Fuels
Jay Farrell, Professor of Electrical Engineering
Dennis Fitz, Research Faculty, Atmospheric Chamber
Wendy Goliff, Research Faculty, Atmospheric Chamber
Kent Johnson, Research Faculty, Emissions Engines and Fuels
George Karavalakis, Research Faculty, Emissions Engines and Fuels
Rajeev Kumar, Research Faculty, Sustainable Fuels
Heejung Jung, Assistant Professor of Mechanical Engineering
Alfredo Martinez-Morales, Research Faculty, Southern California Research Initiative for Solar Energy
J. Wayne Miller, Research Faculty, Emissions Engines and Fuels
Joe Norbeck, Professor Emeritus of Chemical and Environmental Engineering
Chan Seung Park, Research Faculty, Sustainable Fuels
Marko Princevac, Associate Professor of Mechanical Engineering
Robert Russell, Research Faculty, Emissions Engines and Fuels
Sadrul Ula, Research Faculty, Southern California Research Initiative for Solar Energy
Charles Wyman, Professor of Chemical and Environmental Engineering
Yushan Yan, Professor of Chemical and Environmental Engineering

Postdoctoral Scholars

Gookyoung Heo, Atmospheric Chamber
Deepti Tanjore, Sustainable Fuels
Guoyuan Wu, Intelligent Transportation Systems
Qian Xu, Atmospheric Chamber
Taiying Zhang, Sustainable Fuels
Anh Vu, Intelligent Transportation Systems
Zhongbin Zhuang, Intelligent Transportation Systems

Students

During 2011, 68 graduate students and 74 undergraduate students worked as part of CE-CERT research programs.

Graduate Students: Scott Boskovich, Phillip Brendecke, Charles Cai, Tanfeng Cao, Chia-Li Chen, Christopher Clark, Jaclyn DeMartini, Poornima Dixit, Xin Fan, Michael Giordano, Xiadi Gao, Garima Goyal, Michael Lee Grady, Ali Guvenc, Nicholas Robert Gysel, Maryam Hajbabaei, Corey Hardin, Noam Hart, Wei He, Seyedehsan Hosseini, Sangran Hu, Qiu Jin, Yi Jin, Mary Kacarab, Mohammad Yusuf Khan, Hongjia Li, Lijie Li, Yang Li, Tachoon Lim, Ying Liu, Zhongzhe Liu, May Ling Lu, Xiaoming Lu, Ji Luo, Qian Luo, Huiqing Ma, Heather McKenzie, Ian Miller, Nikhil Rajan Nagane, Shunsuke Nakao, Anh Nguyen, Hansheng Pan, Stefan Pitzek, Derek Price, Melina Roshandell, George Scora, Daniel Zachary Short, Amornrat Suemanotham, Sarath Suvarna, Yueh-Du Tsai, Ping Tang, Xiaochen Tang, Yoothana Thanmongkhon, Rathavut Vanitsthian, Anh Vu, Diep Vu, Xiaochong Wang, Haitao Xia, James Yang, Qichi Yang, Minyoung Yun, Haiyu Zhang, Huiling Zhang, Yan Zhang, Yanqi Zhang, Yulin Zhang, Sheng Zhao, Zhongqing Zheng.

Undergraduates: Lorelei Adams, Victor Aguilar, Hyo Un Michelle Ahn, Marjan Askari, Dionicio Ayala, Shabriha Bashar, Sarah Bates, Justin Bautista, Tony Beavers, Samir Benouar, Phillip Brendecke, Amy Marie Calgaro, Dante Carrillos, Kevin Castillo, Neil Chaney, Rosalva Chavez-Ramirez, Tiffany Chea, William Chen, Eduardo Cuevas, Hayden Dahl, Joseph Dean, Joshua Scott Dolson, Wyatt Duvall, Sean Engineer, Carlos Espinoza, Duresameen Farooq, Alex Gamarra, Oscar Garcia, Payam Goshtasbi, Daniela Gutierrez, James Gutierrez, Seyed Hashemi, Daniel Hormozi, Peter Seing Huang, Nicholas Jarak, Mary Kacarab, Masato Koizumi, Thomas Kwan, Claudia Lau, William Lichtenberg VI, Gary Liu, Rachel Lomax, Kyle Loggins, Sean McClanahan, Joseph Menke, Shawn Miata, Faith Morel, Sasan Mojgani, Daniel Morton, Jeremy Nelson, Duc Minh Nguyen, Duyen Nguyen, Ray Nishii, Robin Picchi, Joseph Pichette, Rajesh Reddy, Ali Roohani, Jesus Adrian Sahagun, Daniel Sandez, Srihari Santhanam, Eric Seo, Ryan Sixt, Letia Solomon, Stephanie Stasiuk, Hasam Taghizadeh, Anh Thach, Min Thai, David Torres, Kathy Bao Vang, Tiffany Viggiano, Mark Jonathan Villela, Charles Wardle, Nigel Williams, Larissa Yates.

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