

NEWS FROM THE UNIVERSITY OF CALIFORNIA ENERGY INSTITUTE

UC Fuel Cell Research Leads the Nation

In the last year, the nation has grown increasingly aware of fuel cell technology thanks to media excitement and increasing federal government interest. Long before the public caught on, however, three University of California research centers were deeply involved in fuel cell research. They are UC Davis's Institute of Transportation Studies (ITS-Davis), UC Irvine's National Fuel Cell Research Center (NFCRC), and UC Riverside's College of Engineering Center for Environmental Research and Technology (CE-CERT).

"The University of California has, within its institution today, the leading fuel cell programs both nationally and internationally," says Scott Samuelsen, director, NFCRC. California is the world's test bed for the evolution of both stationary and transportation fuel cell technologies.

The diverse research capabilities across the campuses position the system to continue its leading role, adds ITS-Davis Director Dan Sperling. He believes UC fuel cell research has major implications for economic, environmental and social well being. "Fuel cells could be one of the two or three most important technologies of the 21st century."

Each UC campus traditionally has developed its own personality and academic strength. So it goes with fuel cell research, says CE-CERT Associate Director Matthew Barth. "The individual research focus of the three campuses is very complementary and has evolved naturally." UC Irvine focuses on stationary fuel cells. UC Davis emphasizes materials and automotive applications. UC Riverside concentrates on materials and hydrogen.

What the three campuses have in common is a non-traditional approach to research and teaching. Each is reaching out to link scholarly and laboratory research with practical applications, in collaboration with the public and private sectors. All three are leveraging federal, corporate and other external funds to expand their research and education programs in anticipation of heightened demand for knowledge and technology transfer.



Paul Erickson uses this first-generation liquid-fueled fuel cell bus as a research and education tool at UC Davis.

The three campuses also benefit from interactions with the national labs on fuel cell and hydrogen research. Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories are all engaged in basic research, which complements the work within the UC system.

UC Irvine's National Fuel Cell Research Center

Approximately 70 percent of NFCRC's work is on stationary fuel cells, the market most likely to reach commercialization first. NFCRC's research focuses on three disciplines: core engineering design and research, optimum deployment strategies for distributed generation (DG), and grid connectivity issues.

NFCRC researchers are working on next-generation solid oxide and molten carbonate fuel cells. These high temperature fuel cells are gaining traction in stationary applications because they are highly efficient, their waste heat is high quality and can be recovered in many ways, and they are relatively insensitive to fuel quality compared to fuel cells being explored for transportation applications. Their high operating temperature, while a great benefit for stationary applications, is a major drawback for most transportation uses. Other core engineering work includes creating design and analysis tools, and developing ultra-high efficiency "hybrid"

Continued on page 2

UC Fuel Cell Research *continued from page 1*

power plants that integrate fuel cell and gas turbine technology. NFCRC's experience with low emission gas turbine technology dating from 1970 provides a critical perspective for the hybrid application.

NFCRC's DG research involves integration of fuel cells into buildings so that the heat produced as a byproduct of the fuel cell-generated electricity can be utilized effectively, for example, to drive advanced absorption chiller units for air conditioning. Its grid connectivity work examines issues important to electric utilities, such as connecting a DG unit to the power grid without endangering lines workers, and successfully converting the generator's DC voltage to the grid's AC voltage.

The DG deployment and grid connectivity issues are market hurdles, Samuelsen says. "We don't want fuel cells to be in the Smithsonian in 20 years. We need to make the technology work, but we also need to meet market and political needs."

On the transportation front, NFCRC is testing a Toyota Highlander fuel cell car through its ZEVNET (Zero Emission Vehicles Network Enabled Transportation) shared-use vehicle program and deploying hydrogen-refueling infrastructure in the public domain. UC Irvine and UC Davis are the only U.S. institutions that are actively testing the Toyota cars.



UC Davis and UC Irvine are the only U.S. institutions testing the Toyota fuel cell vehicle.

UC Davis's Institute of Transportation Studies

ITS-Davis's transportation research and education program ranges from basic science to policy analysis, an approach that meets the complex challenges facing fuel cells and the industries embracing them.

"The world's largest industries, the automotive and energy industries, are among those most affected by climate change, oil supply disruptions, and global instability. Fuel cells reduce those impacts, and that's why these companies, and society more broadly, are paying attention," says Sperling.



NFCRC's 220 kW solid oxide fuel cell/gas turbine hybrid. Partners: Southern California Edison, Siemens Westinghouse Power Corporation, U.S. DOE, South Coast Air Quality Management District, California Energy Commission, and Electric Power Research Institute.

Affiliated faculty from multiple UC Davis departments — Biological and Agricultural Engineering, Chemical Engineering and Materials Science, Environmental Science and Policy, and Mechanical and Aeronautical Engineering — collaborate with ITS-Davis research staff on fuel cell research. In total, 20 faculty and researchers work in diverse fuel cell and hydrogen disciplines, including materials science, catalysis, systems development and durability, fuels and reformation, environmental analysis, economics, and market research.

For example, Christie-Joy Brodrick (ITS-Davis) and Harry Dwyer (Mechanical and Aeronautical Engineering) are designing and analyzing fuel cells as auxiliary power units in tractor-trailer trucks. Bob Moore (ITS-Davis), with a group of grad students and post-docs, recently completed a five-year Fuel Cell Vehicle Modeling Program on fuel cell performance and efficiency. Others are road-testing two Toyota Highlander fuel cell cars and analyzing consumer acceptance.

Two new faculty members enhance the campus's expertise. Joan Ogden (Environmental Science and Policy), a renowned hydrogen energy expert from Princeton, will help launch a new program to address the transition to a hydrogen economy. And Paul Erickson (Mechanical and Aeronautical Engineering), an expert on fuels reformation, is conducting systems and durability research on phosphoric acid fuel cells in the first liquid-fueled fuel cell bus ever constructed.

UC Riverside's College of Engineering Center for Environmental Research and Technology

CE-CERT also offers a broad program of interdisciplinary basic and applied research on transportation issues.

Continued on page 3



CE-CERT researchers with fuel cell cart.

Most of its current fuel cell research focuses on materials engineering. Yushan Yan, associate professor of Chemical Engineering, is researching novel applications of zeolite thin films and coatings for waste heat recovery in fuel cell vehicles. Zeolites are a class of microporous crystalline materials that have been widely used in powder form as catalysts and separation media. Yan is researching whether these films, used in computer and aerospace applications, may also have utility in high temperature proton conductive membranes such as in a proton exchange membrane fuel cell.

In CE-CERT's Transportation Systems and Vehicle Technology Research Laboratory, researchers have worked with Yamaha and evaluated a small fuel cell utility vehicle to learn about energy management and vehicle control strategies. CE-CERT also worked with private companies to convert a heavy-duty tractor trailer to electric drive and outfit it with a fuel reformer capable of producing usable hydrogen from diesel fuel for the U.S. Army.

CE-CERT's fuel cell research is relatively new, however its work with hydrogen fuel began 10 years ago. CE-CERT, says Barth, sees hydrogen internal combustion engine technology as a stepping-stone to a true hydrogen economy. "It's quicker, and more cost-effective short term technology."

If the hydrogen economy is the long term goal, the UC system is well positioned to lead the research community in this direction. The next issue of *Energy Notes* will examine hydrogen research across the UC system. ■

UC RESEARCHERS:

Academia Must Do More

For all the excitement over fuel cells and hydrogen in the media and in political and investment circles, academia should be doing more, say leaders in UC's fuel cell research arena.

Dan Sperling, director of the Institute of Transportation Studies at UC Davis, and Scott Samuelsen, director of UC Irvine's National Fuel Cell Research Center lament the general lack of formal curricula, funding, research, and faculty training on fuel cells and hydrogen. While they are both proud of their programs' accomplishments, they challenge other UC campuses and institutions around the world to invest in the needed academic and research infrastructure, applied science, and policy to ensure that society can effectively transition to the much anticipated hydrogen economy.

"I don't know of another technology, besides transistors and solid state electronics, that will pervasively expand into all aspects of society," says Samuelsen, "and yet very little is going on in universities today."

Adds Sperling, "If we're going to transform our energy and transportation systems in this country, then every major university should be conducting research in this area." He notes that there is plenty of opportunity for cooperation and collaboration among UC campuses and other leading institutions. "UC is at the leading edge of research in this area. But there's room for much more involvement."

Matthew Barth, associate director, UC Riverside's College of Engineering Center for Environmental Research and Technology, notes that several UC campus leaders are beginning to discuss a multi-campus initiative. "Now is our chance to get organized, to show the world how well-rounded we are as a system and as individual campuses within a system, and to present a comprehensive fuel cell research education initiative."

Profile:

Frank A. Wolak, Visiting Scholar

Frank Wolak, a longtime collaborator with UCEI, spent an intense spring quarter at UCEI as a Center for the Study of Energy Markets (CSEM) visiting scholar. Wolak, a professor in the Department of Economics at Stanford University, slogged through the infamous Bay Area traffic to exchange ideas and potential solutions to the California electricity quagmire with other CSEM researchers.

“The reason I find research on electricity markets interesting is the interaction between rational political actors in the government and rational economic actors in the marketplace,” Wolak told *Energy Notes*.

A proponent of restructuring and competitive markets, Wolak believes that deregulated wholesale and retail markets can bring benefits to consumers. “If we’re not delivering benefits to consumers, then I don’t understand why we are restructuring,” he stated.

He acknowledged that most U.S. consumers have yet to benefit significantly from electricity restructuring, but he pointed to restructuring successes in Scandinavia, England and Wales, and Australia.

In California, conflicts between state and federal oversight of the electricity industry have hindered effective implementation, he said. “The state is working to protect state interests, while federal regulators are working to protect national interests. Even though they may share a common goal, they have very different ideas about how to achieve a competitive wholesale market, which leads to conflicts.”

He identified three elements necessary for a successful wholesale market: incentives for and the ability for load-serving entities (retailers) to hedge spot price risk; consumer demand actively involved in the wholesale market; and regulatory mechanisms that cause economically beneficial transmission upgrades to occur in a timely manner. “Unfortunately, until very recently, there was no movement on these issues,” he lamented. “In some ways, the lessons of the California energy crisis appear to have not been learned.”

Market designers often ignore what economists call the individual rationality constraint, which implies that once market rules are set, privately owned firms will maximize profits subject to those market rules.

“Designing a market assuming that firms do not take advantage of profit-making opportunities is unrealistic,” Wolak said. Economists specialize in analyzing how firms will maximize their profits for a given set of market rules. This helps them design market rules that best serve the public interest.

As chairman of the ISO Market Surveillance Committee, which interacts with federal and state policy makers, Wolak believes that California must either embrace the wholesale market with its retail market policies or return to the vertically integrated regulated regime. Hybrid solutions, which combine retail market policies from the vertically integrated regime with a wholesale market, are recipes for disaster, he said.

“If we’re not delivering benefits to consumers, then I don’t understand why we are restructuring.”

“In some ways, the lessons of the California energy crisis appear to have not been learned.”



“One lesson I have learned from the crisis is not to be understated because people don’t hear it. In the past I didn’t want to be alarmist. Now, I believe it is important to alert as many people as possible of shortcomings in the wholesale and retail market design.” Wolak is encouraged by the fact that state policymakers appear to be getting the message on the importance of a retail market that supports the wholesale market.

For all the frustrations of the energy market, Wolak finds great reward in his work. He has found that combining forces with UCEI’s Severin Borenstein and Jim Bushnell has significantly enhanced his research productivity. “Severin and Jim have made UCEI an internationally renowned center for research on energy markets. Much of their efforts don’t directly benefit them; instead they benefit the community of scholars. By collaborating with them, I receive some of the benefit, and I contribute to their efforts.” ■

Fun and Research at CAMP UCEI



A small group of energy economists from around the world gathered at UCEI's offices during the week of August 25 to share ideas on electricity issues and discuss potential new areas of study.

Each day, visiting and UC researchers heard an informal talk on work in progress during lunch, and attended a regular seminar on near-completed research in the afternoon. Topics included auction design, cross-state comparisons of market performance, new plant investment incentives, effects of long-term contracts, and many others.

A few of the participants will be visiting researchers at UCEI this fall. Watch the UCEI Web site's Fall Seminar Schedule (www.ucei.berkeley.edu/seminar_fall03r.htm) for information on future seminars. ■



UCEI Visiting Research Associate Stephen Holland leads a session.



An informal lunchtime talk on the RECLAIM market in Southern California.



Meeting to discuss data on plant emissions.



Jun Ishii, assistant professor, UC Irvine, left, and Steve Puller, assistant professor, Texas A&M University discuss estimation of competitive behavior.



Chris Knittel, UC Davis assistant professor, Frank Wolak, Stanford professor, and Jim Bushnell, UCEI, clearly enjoy their work.

UC SYSTEM ENERGY RESEARCH CENTERS

UNIVERSITY OF CALIFORNIA

Energy Institute;
<http://www.ucei.berkeley.edu/ucei/>

California Institute for Energy Efficiency; <http://ciee.ucop.edu/>

Institute of Geophysics and Planetary Physics; <http://www.igpp.ucla.edu/>

Center for Information Technology Research in the Interest of Society;
<http://www.citris.berkeley.edu/>

Transportation Center;
<http://www.uctc.net/>

UC BERKELEY

Center for the Built Environment;
<http://www.cbe.berkeley.edu/>

Combustion Analysis Laboratory;
<http://www.me.berkeley.edu/cal/>

Combustion Process Laboratories;
<http://www.me.berkeley.edu/cpl/>

Environmental Combustion Group;
<http://www.me.berkeley.edu/cbl/>

Center for Environmental Design Research; <http://www.cedr.berkeley.edu/>

Partners for Advanced Transit and Highways;
<http://www.path.eecs.berkeley.edu/>

Petroleum Engineering Group;
<http://www.mse.berkeley.edu/petroleum/PE.html>

Plasma Theory and Simulation Group;
<http://ptsg.eecs.berkeley.edu/>

Renewable and Appropriate Energy Laboratory; <http://ist-socrates.berkeley.edu/%7Erael/>

Institute of Transportation Studies;
<http://www.its.berkeley.edu/>

UC DAVIS

California Wind Energy Consortium;
<http://cwec.ucdavis.edu/>

California Institute of Food and Agricultural Research;
http://foodsci.ucdavis.edu/CIFAR/HOME_PAG.HTM

National Institute for Global Environmental Change;
<http://nigec.ucdavis.edu/>

Institute of Transportation Studies;
<http://www.its.ucdavis.edu/>

Center for Urban Forest Research;
<http://wcufr.ucdavis.edu/>

UC IRVINE

Advanced Power and Energy Program;
<http://www.apep.uci.edu/>

National Fuel Cell Research Center;
<http://www.nfrcr.uci.edu/>

Pacific Rim Consortium: Energy, Combustion and the Environment;
<http://www.parcon.uci.edu/>

UCI Combustion Laboratory;
<http://www.ucicl.uci.edu/>

Fusion Energy and Pulsed Power Research; <http://fusion.ps.uci.edu/>

Power Electronics Laboratory;
<http://www.eng.uci.edu/pel/pel.html>

Institute of Transportation Studies;
<http://www.its.uci.edu/>

UC LOS ANGELES

Center for Environmental Risk Reduction; <http://www.cerr.ucla.edu/>

Fusion Science and Technology Center;
<http://www.fusion.ucla.edu/>

Plasma Science and Technology Institute;
<http://www.physics.ucla.edu/psti/>

UC RIVERSIDE

Center for Environmental Research and Technology; <http://www.cert.ucr.edu/>

Institute of Geophysics and Planetary Physics; <http://www.igpp.ucr.edu/>

UC SAN DIEGO

Center for Energy Research;
<http://cer.ucsd.edu/>

Advanced Energy Technology Group;
<http://www.ferp.ucsd.edu/index.shtml>

Combustion Division;
<http://maemail.ucsd.edu/combustion/>

Fusion Energy Division;
<http://aries.ucsd.edu/FERP/>

Scripps Institution of Oceanography;
<http://sio.ucsd.edu/>

UC SANTA BARBARA

Institute for Crustal Studies;
<http://quake.crustal.ucsb.edu/ics/>

UC SANTA CRUZ

Institute of Geophysics and Planetary Physics; <http://igpp.ucsc.edu/>

UC/DOE LABS

E.O. Lawrence Berkeley National Laboratory; <http://www.lbl.gov/>

Accelerator and Fusion Research Division;
<http://www-afrd.lbl.gov/afrd.html>

Earth Sciences Division;
<http://www-esd.lbl.gov/>

Environmental Energy Technologies Division; <http://eetd.lbl.gov/>

Energy Analysis Department;
<http://eetd.lbl.gov/EA.html>

Building Technologies Department;
<http://eetd.lbl.gov/BT.html>

Indoor Environment Department;
<http://eetd.lbl.gov/IE.html>

Advanced Energy Technologies Department;

<http://eetd.lbl.gov/AET.html>

Atmospheric Sciences Department;
<http://eetd.lbl.gov/AQ.html>

Lawrence Livermore National Laboratory; <http://www.llnl.gov/>

Energy and Environment Directorate;
<http://en-env.llnl.gov/>

Fusion Energy Program;
<http://fusion-energy.llnl.gov/>

National Ignition Facility;
<http://www.llnl.gov/nif/>

Los Alamos National Laboratory;
<http://www.lanl.gov/>

Energy and Sustainable Systems Program; <http://www.lanl.gov/energy/>

Fusion Energy Sciences Program;
<http://fusionenergy.lanl.gov/>

These are the UC units that are focused on energy research. Many other units also conduct energy research as a part of their mission, however due to space limitations, we only included those for which energy is the primary focus. A more comprehensive list of energy-related organizations is on the UCEI Web site at <http://www.ucei.berkeley.edu/nrgorgi.html>. Please contact UCEI if you believe we have overlooked an energy-research unit. The University's Office of Research Web site (<http://www.ucop.edu/research/>) lists research units and Web sites of the 10 campuses and three DOE laboratories.

Short Takes

UCEI Moving Again!

UCEI will move to its permanent location on a date that continues to move. The best information indicates that the Institute's move to 2547 Channing Way (also known as the Shorb House) will take place at the end of October 2003. Telephone numbers will not change. Seminars will be held at a newly refurbished conference room on the main floor. Check the UCEI Web site for more information on the move and the seminar schedule. ■

UCEI Grant Solicitation Approaching

In early November, UCEI will make available its grant proposal application package for the 2004-2005 cycle. Eligible UC faculty and researchers can either check the UCEI Web site for information as it becomes available or ask to be put on the e-mail notification list for the application package. Just send an e-mail to knotsund@uclink.berkeley.edu and you'll receive the package electronically. ■

Second Annual CSEM Policy Conference

Mark your calendars for November 14! Last year's CSEM Policy Conference was so well received that this year's conference will be held in a larger venue, at the California Secretary of State Building at 1500 11th Street in Sacramento. The conference is designed to address the hot electricity policy topics of the day and will include interactive Q&A opportunities. It is offered through a grant from the California Energy Commission and open to the public at no charge. Watch the UCEI Web site for more details as the date draws near! ■

Competition in Developing Countries:

EXAMINING BENEFITS AND FEASIBILITY



Amol Phadke

The push to reform the power industry extends well beyond California's and the nation's borders. Many countries are pursuing competition in the hope it will improve efficiency and lower prices. The model for successful deregulation, however, may be different for developed countries than for developing nations.

UCEI research assistant and Ph.D. student Amol Phadke examined the feasibility of competition in his home state of Maharashtra, on the west coast of India, for his Master's thesis. He found that effective competition would likely be difficult, if not impossible, to implement there. Compared to developed country markets, the size of the electricity sector is small, reserve margins are lower because of under-investment in the sector, the number of players in the market is likely to be lower, and the presence of large centralized power plants in small markets increases market power problems. As a result, competition among firms may be difficult to achieve and consumers may actually face higher prices than they did before the market was restructured.

Although the factors affecting competition in this research were specific to India, Phadke believes other developing countries may experience similar challenges. "People haven't really looked at the feasibility of competition in a developing country context. They need to look more closely," Phadke contends. "Currently, the reform efforts are focused on privatization in anticipation of significant gains from competition in the future. But if competition is not feasible, it's not clear that the private sector will achieve lower prices and costs, so one should think hard about the focus of reforms," he warns.

Over the summer, Phadke spent three weeks at the World Bank examining issues of open access to transmission and distribution in India and other developing countries.

"I'm happy that I can do some work that is relevant and that may help in forming appropriate policies," he says. He credits UCEI's extensive analysis on electricity markets, especially competition, in helping him apply the body of knowledge to developing markets. ■

