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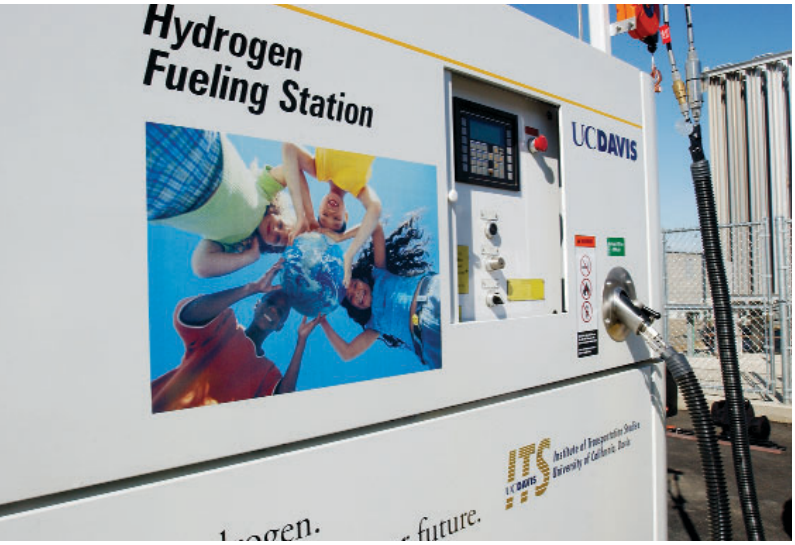
NEWS FROM THE UNIVERSITY OF CALIFORNIA ENERGY INSTITUTE

Hydrogen Economy

UC RESEARCH GUIDES TRANSITION FROM TODAY'S TO TOMORROW'S ENERGY



UC Davis recently installed a hydrogen fueling station to support its research on fuel cell vehicles. UC Irvine will install three hydrogen stations in Orange County through a partnership with the South Coast Air Quality Management District.

As public awareness and acceptance of hydrogen's potential to shift the world's energy paradigm continue to grow, several University of California campuses are expanding their research programs to address the much-anticipated hydrogen economy.

President Bush's vocal support of hydrogen and Governor Schwarzenegger's ambitious Hydrogen Highways proposal, which seeks to establish a network of hydrogen fueling stations every 20 miles on California's major interstates by 2010, lend vital support to a nascent industry, says UC Irvine's Scott Samuelsen, director of the National Fuel Cell Research Center and the university's Advanced Power and Energy Program. "Industry is now willing to come out of the woodwork, acknowledge and accelerate its work in hydrogen, all because of the political advocacy that has so effectively been stated at the federal and state level."

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Effects of Speculators in Deregulated Energy Markets

As debates over the value of restructuring wholesale electricity markets continue, market operators are divided over just who should be allowed to trade in these markets.

Some argue that only actual producers and consumers should be trading, while others say that speculators should also be allowed, as they are in other commodity markets. Celeste Saravia, research assistant at UCEI and doctoral candidate in economics at UC Berkeley, is concluding theoretical and empirical research that could provide important guidance on this topic.

Saravia's model provides insight about the effects speculators may have on production decisions and price levels in New York's restructured electricity market. The model

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"Yes, the challenges are huge, and the payoffs decades in the future, but there are no other more promising long-term options."

—Dan Sperling, UC Davis

The state is flexing its research arm, its universities, to help plan future hydrogen strategies. Both UC Irvine and UC Davis expect to be involved. The Institute of Transportation Studies at UC Davis will likely play a key role in turning the governor's vision into a plan, says director, Dan Sperling. "We will develop the tools necessary to evaluate different hydrogen plans and strategies that the state could adopt."

Contributing to the state and national dialogue is an important part of ITS-Davis's hydrogen program. "In the end, hydrogen is very likely going to be a major part of our whole energy system," Sperling notes, given the inevitable decline of petroleum. "Yes, the challenges are huge, and the payoffs decades in the future, but there are no other more promising long-term options."

Concern over air pollution, carbon dioxide and global climate change, and the promise of fuel independence are driving the hydrogen agenda. In California, passenger vehicles are responsible for about 40 percent of greenhouse gas emissions, according to the California Air Resources Board. "When you examine the projected number of automobiles in the world over the next 30 years, the potential increase in the CO_2 burden is alarming," says Samuelsen.

Hydrogen is appealing because it can be produced domestically from renewables or from fossil fuels in a process that can capture the CO_2 at the central production source. Adds UC Davis professor Joan Ogden: "To transition from where we are now to a future that's so different is an overwhelming but also energizing set of possibilities — because hydrogen can be made from so many different sources."

The transition, however, is filled with daunting challenges, many of which were outlined last month in a report from the National Research Council. The NRC committee, on which Sperling served, noted that a transition to hydrogen in the next 50 years could significantly change the U.S. energy economy, but technical, economic, infrastructure, and social barriers need to be overcome.

One way to address infrastructure and cost issues is to devise ways to generate society's two main energy

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CONTRIBUTING TO THE HYDROGEN DIALOGUE BEYOND ACADEMIA

As co-director of ITS-Davis's Hydrogen Pathways program, Joan Ogden is helping shape the interdisciplinary effort to seek solutions to the technical, cost, infrastructure and market issues facing the hydrogen economy.

"It's important to me to be able to contribute to the process that will influence how hydrogen is treated."

—Joan Ogden, UC Davis

A physicist, most of Ogden's work has involved technical and economic assessments of new energy technologies, especially renewable fuels, hydrogen, and fuel cells. She has written extensively on energy topics, including a book and numerous peer-reviewed journal articles, book chapters and conference presentations. She joined the UC Davis faculty last fall after almost 20 years as a researcher at Princeton.

Ogden has served on committees and working groups convened by the U.S. Department of Energy on future energy technologies and strategies. She was one of only a few academic researchers invited to participate in the U.S. DOE Hydrogen Vision and Roadmap process in 2001-2002. She headed the systems integration team that helped, as she says, "put together the pieces" for a key document that supported the FreedomCAR program announcement in 2003. In early 2003, she testified before Congress on the economics of hydrogen systems. She is now active in H2A, a group of hydrogen analysts convened by U.S. DOE to develop consensus on hydrogen costs in order to establish a baseline for future cost estimates. She heads the H2A team studying delivery strategies for hydrogen.

She also was the only academic to present research on hydrogen infrastructure to a panel of the National Research Council, which last month released a report on hydrogen's challenges. "A document like this has a long life and represents a very careful review of the issues," she says.

POWER Research Conference Draws International Attendance

Ninth Annual
POWER
Research Conference

The Ninth Annual POWER Research Conference on Electricity Industry Restructuring was held on March 19 in Berkeley. Each year, the conference, which is organized by UCEI's Center for the Study of Energy Markets, brings together researchers, policy makers and practitioners from around the world to discuss the pressing issues of electricity industry restructuring. The program addressed critical policy concerns including price volatility, forward contracting, resource adequacy, system reliability, market power, and efficiency.

This year's program included the following papers:

- "A Comparison of Price Patterns in Deregulated Power Markets," Peter Flynn and Katherine Ying Li, University of Alberta
- "The Natural Number of Forward Markets for Electricity," Hiroaki Suenaga and Jeffrey Williams, UC Davis
- "Reliability and Competitive Electricity Markets," Paul Joskow, MIT and Jean Tirole, Toulouse and MIT
- "Resource Adequacy and Market Power Mitigation via Option Contracts," Hung-po Chao, EPRI and Robert Wilson, Stanford University
- "Testing Strategic Models of Firm Behavior in Restructured Electricity Markets: A Case Study of ERCOT," Steve Puller, Texas A&M and Ali Hortacsu, University of Chicago
- "Market Structure and Competition: A Cross-Market Analysis of U.S. Electricity Restructuring," James Bushnell, UCEI, Erin Mansur, Yale University and Celeste Saravia, UC Berkeley and UCEI
- "Recent Blackouts in the U.S., Canada, and Continental Europe: Is Liberalisation to Blame?" Janusz Bialek, University of Edinburgh
- "Has Restructuring Improved Operating Efficiency at U.S. Electricity Generating Plants?" Kira Markiewicz, UC Berkeley, Catherine Wolfram, UC Berkeley and UCEI, and Nancy Rose, MIT

Profile:

Steven L. Puller, Visiting Researcher

Sometimes even the best-laid plans get tossed. Steven Puller entered graduate school at UC Berkeley in 1995 fully intending to study environmental economics, but instead became hooked on the economics of electricity markets. Puller was then and is still drawn to electricity research because he feels it is one of the rare opportunities to test economic theory in the real world.

Now an assistant professor of economics at Texas A&M University, Puller returned to Berkeley last summer and fall as a UC Energy Institute visiting researcher. This month, he is presenting a new paper that examines electricity generating firms' bidding behavior in the Texas electricity spot markets at the 2004 POWER Research Conference.

"Economic theory is pretty rich in predicting how generators will bid, but we wanted to go beyond the theory to the real-world data to determine exactly what is happening." While there is an extensive literature on the economic theory of auctions, it's seldom that those theories can be tested with real data.

Puller and colleague Ali Hortacsu, an assistant professor at the University of Chicago, focused their research on Texas's spot market, the only electricity market in Texas subject to centralized market bidding. Unlike California's original market design, most of the transactions in Texas are bilateral contracts between power generators and retail providers, which are then scheduled through the grid operator, ERCOT.

Data from the first year of deregulation, September 2001 to July 2002, reveal interesting insights. "The data show that firms generally are behaving as theory would predict, but it appears there's a learning curve. At the beginning of markets you might see some real inefficiencies," Puller says. A few generating firms clearly recognized the opportunities for profitable bidding, while many tended to avoid the market, even though it appears it was in their interest to participate. This tendency to avoid the market increased the costs of procuring power. "It's been interesting to see the evolution of bidding behavior over time," Puller notes. "We're learning a lot about how the game is really played."

Puller believes this work can be valuable to electricity regulators who want to determine how generators are bidding, to industry representatives who want to learn how to bid, and to economists who want to test predictions of auction theory. The methodology developed for this research may be useful to electricity market monitors who have enough data to evaluate the competitiveness of their market, but lack the resources, time, or tools to use those data, he adds. "What we did is remarkably simple, but doesn't appear to have been done much before."

He credits the atmosphere at UCEI as "the ideal environment in which to perform electricity market research." And although he is glad to be back in Texas, where he teaches graduate and undergraduate-level courses, he admits he's already missing the west coast. "The food in Berkeley is much better!" he laments.

"It's been interesting to see the evolution of bidding behavior over time. We're learning a lot about how the game is really played."

"We wanted to go beyond the theory to the real-world data to determine exactly what is happening."

Further Reading:

"Testing Strategic Models of Firm Behavior in Restructured Electricity Markets: A Case Study of ERCOT," Puller, Steven L., and Ali Hortacsu, CSEM Working Paper #125, March 2004.

"Pricing and Firm Conduct in California's Deregulated Electricity Market," Puller, Steven L., August 2002. UCEI POWER Working Paper PWP-080R.

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carriers, hydrogen and electricity, from one power plant or station. Doing so implies a transformation of both our electricity and transportation energy systems, but the efficiencies of an integrated hydrogen-electricity facility and system make it an attractive prospect. Researchers at UC Irvine and UC Berkeley are following this track.

In a multi-year U.S. Department of Energy project led by Ashok Rao, researchers in UC Irvine's Advanced Power and Energy Program have developed the conceptual and engineering design of a 100 MW to 500 MW power plant that would generate electricity and hydrogen from coal or natural gas. The electricity would be distributed through the grid, while the hydrogen could fuel stationary fuel cells for buildings or provide direct fuel for cars. The future power plant concepts meet lofty DOE-established goals of high efficiency and minimal environmental impact.

Another UC Irvine project led by Jack Brouwer at the National Fuel Cell Research Center is evaluating the potential for high-temperature stationary fuel cells to produce electricity for buildings and utilize the waste heat to create hydrogen.

At UC Berkeley, Tim Lipman and Dan Kammen in the Energy and Resources Group have developed a model to analyze the costs and environmental impacts of energy stations. A prototype operating in Las Vegas reforms hydrogen from natural gas. The hydrogen powers a 100 kW stationary fuel cell that generates building electricity. The hydrogen also fuels cars. "Our goal is to be able to calculate the overall costs of this kind of system," explains Lipman.

The campuses have other projects. UC Irvine has a strategic alliance with General Electric to develop advanced reformer technology. UC Berkeley is exploring ways to store renewably generated electricity during off-peak periods by using electrolysis to make hydrogen. For the last several years, UC Riverside has been engineering and testing internal combustion engine vehicles that run on hydrogen. UC Davis is evaluating early hydrogen markets, fueling station design and distribution infrastructure, investment risks, and market response to hydrogen-powered cars. UC Davis, UC Berkeley and UC Irvine are all involved in a variety of lifecycle analysis projects that evaluate the energy, environmental, and economic costs of hydrogen from cradle to grave.

UC nuclear engineers are working in the international Next Generation Nuclear Plant (NGNP) program, which is developing a high-temperature nuclear power plant that uses heat to produce both hydrogen and electricity. Per Peterson of UC Berkeley's Department of Nuclear Engineering is developing heat exchange components for such a power plant. Initial designs will probably involve advanced helium-cooled reactors and compact helium gas turbine technology. Other promising concepts include a molten fluoride salt-cooled reactor, based on a technology studied over the past decade in Berkeley for use in fusion power plants. Peterson is collaborating with researchers at Oak Ridge and Sandia national laboratories to study fission power plants using molten-salt coolants. This technology holds promise for reducing the capital costs of producing both hydrogen and electricity.

The Las Vegas Energy Station, where a hydrogen generator (left) installed by Air Products and Chemicals, Inc., produces hydrogen through the reforming and purification of natural gas. This hydrogen fuels vehicles and Plug Power's PEM (proton exchange membrane) fuel cell (right), which provides electrical energy to the Las Vegas grid.

ITS-Davis is one of the few university programs that approach hydrogen research from a broad perspective that includes social sciences, environmental analysis, management, economic analysis, and pure engineering. A 20-member interdisciplinary research team of students, post-docs, and faculty are engaged in Davis's multi-year Hydrogen Pathways program. It seeks to address the technical, economic, market, and policy implications of a transition to hydrogen in the transportation sector.

Not all UC researchers are as optimistic about a hydrogen future. Alex Farrell, assistant professor in Berkeley's Energy and Resources Group, believes hydrogen provides a convenient political distraction from other readily available strategies for reducing CO_2 and air pollution, and for increasing energy independence. "There are faster, cheaper ways to reduce oil imports and pollution now. And in the long run, placing all the research emphasis on hydrogen is clearly a risky strategy when there are other options," Farrell says.

Most researchers would likely argue that hydrogen, alone, is not monopolizing research attention, but there are two areas where hydrogen research, in the short

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Short Takes

CSEM Spring Policy Conference

Keep an eye out for information on the semi-annual CSEM Policy Conference, which will be held in May. The conference is designed to present the policy implications of CSEM research. An interactive Q&A session brings in different views and promotes lively discussions. Check the UCEI Web site (www.ucei.org) for details on date, location and program agenda. The Policy Conference is offered through a grant from the California Energy Commission and open to the public at no charge.

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predicts that if speculators are not allowed to trade, firms with market power will charge very high prices in the futures market and that the difference between the futures price and spot price will be greater than a simple risk premium. The addition of speculators prevents firms with market power from charging very high prices in the futures market. This results in an overall decrease in the average procurement cost of electricity. The model also predicts, however, that the quantity of electricity produced by firms with market power decreases, resulting in less efficient production.

Her empirical examination of the New York electricity market analyzes changes that have occurred since the first two years of deregulation, when speculators were prohibited from trading.

"Hopefully, my work will help regulators think about speculators in an equilibrium analysis, and offer guidance as they make decisions about what the role of speculators should be in deregulated electricity markets," Saravia says.

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"We'll kick ourselves in the shins if we move into the hydrogen economy without carefully and proactively addressing the world's environmental needs."

—Scott Samuelsen, UC Irvine

term, is particularly important, Samuelsen believes. First, is the need to identify an odorant so that, for public safety purposes, consumers will learn to recognize a characteristic smell of hydrogen, as they have with Mercaptan in natural gas. Second, is a need to focus on generating hydrogen from renewables, while acknowledging that fossil fuels will likely be a required feedstock in both the short and long term. "We'll kick ourselves in the shins if we move into the hydrogen economy without carefully and proactively addressing the world's environmental needs."

UC Davis and UC Irvine are testing Toyota fuel cell vehicles that run on hydrogen.

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