Board of Advisors Meeting

December 17, 2015

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ENERGY EFFICIENCY CENTER

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Welcome

Welcome Members of the Board of Advisors and Special Guests,

Thank you for participating in our 2015 Board of Advisors meeting. There has never been a more important time to come together to pursue our mission. We look forward to sharing what we are doing and seeking your advice on how to move forward into the next year.

Both California, with its recent legislation (SB350, AB758, AB802), and the world, with its increasing solidarity and collaboration (COP21), are serious about mitigating climate change. And with energy efficiency being front and center in the strategy to accomplish ambitious carbon reduction goals, our Center can play a pivotal role in delivering the adoption of energy efficiency solutions in the real world, both in the near- and far-term, within California and beyond.

We have experienced some great success this past year, including:

- Recruiting new faculty members Vinod Naranayan for our HVACR Center and Ned Spang for the Food Science & Technology Department;
- Winning a prestigious $1.5M cross-disciplinary grant from the Office of Naval Research;
- Deepening our relationship with the California Community Colleges and the California Conservations Corps;
- Advancing important initiatives on realized energy savings, in particular in small and medium-sized commercial buildings; and,
- Supporting the growth and impact of our technical centers of excellence in lighting, HVACR, and water-energy efficiency as they work, among other efforts, to conduct RD&D on: emerging technologies; beneficial codes, appliance standards, and policies; and, advancing affordability in Zero Net Energy communities.

Looking ahead, our researchers have a significant portfolio in front of them. Our lighting team will be addressing the challenges of efficiency, quality, and health impacts of lighting based on both color temperature and color quality; our HVACR team will be pushing for tools that enable climate-appropriate cooling solutions; and our water-energy team will be advancing data platform solutions that enable water conservation and energy savings. But our team has even more work to do, as we think holistically about ways to integrate energy efficiency with demand response, distributed storage and generation, workforce development, financing solutions, and key understandings of social behavior that can empower communities with sustainable low-carbon energy.

As you know, Nicole Biggart retired from her role as Faculty Director for the Center back in April of this year, and although she is still involved as a research faculty member, her absence leaves us with the most pressing and important of tasks: recruiting her replacement. We will talk about these and other important issues while we are gathered together at our Board meeting.

Included in this information packet is an agenda for our meeting, biographies for all of the participants, and background information, which should provide more detail on the most recent and important initiatives we have underway. Although we will not have time in the day's meeting to go into all the work that is covered in the packet; we encourage you to follow-up with us on anything that might be of special interest to you or your team/network.

In all cases, we benefit from your guidance and collaboration. Thank you again for all your support.

With much appreciation,

Benjamin M. Finkelor
Executive Director

Center Overview

The UC Davis Energy Efficiency Center (EEC) was established in 2006 with a challenge grant from the California Clean Energy Fund. It is the first university-based energy efficiency center in the United States to focus on the transfer of technology into the marketplace. The EEC relies upon strong public-private partnerships and collaboration with industry, government, and university partners to meet the demands for energy efficiency innovation, business development, and the growing need for a trained labor force.

The EEC is comprised of 6 Research Centers:

- California Lighting Technology Center
- Center for Water-Energy Efficiency
- Child Family Institute for Innovation
- Plug-in Hybrid & Electric Vehicle Research Center
- Program for International Energy Technologies
- Western Cooling Efficiency Center

Contents

Agenda

Thursday, December 17, 2015

8:00 am **Arrival and Light Refreshments**

8:30 am **Welcome & Introductions**

Ralph Cavanagh, Chairman of the Board

New Board Members:

Mark Vanderhelm, Walmart
Wes Lohec, Chevron
Nicole Howard, SMUD

Special Guests:

Jeanne Clinton, California Public Utilities Commission
Walt Di Mantova, California Community College Chancellor's Office
Lifang Chiang, University of California, Office of the President
Ken Rider, California Energy Commission
Ian Rogoff, California Clean Energy Fund

8:50 am **Center Update**

Ben Finkelor, Executive Director, Energy Efficiency Center (EEC)
Siva Gunda, Director of Research, EEC

Key Topics

- **Faculty Director Search, Transition from Center to Institute, Cross-Cutting Initiatives and Grants**

9:15 am **Discussion**

State and federal policies are driving the need for deeper integration of energy efficiency.

- What are the biggest challenges we face in achieving these policy goals and what strategies can we use to overcome them?
- How are relevant state agencies and our industry partners responding?

Brief Comments:

Ken Rider—SB350, AB758, AB802
Elisabeth Brinton—An IOU perspective and approach
David Jacot—An MOU perspective and approach
Walt DiMantova—Role of workforce development

10:15 am **Break**

10:25 am **UC Davis Initiatives**

Frank Loge, Associate Director, EEC; Center for Water-Energy Efficiency Center; Krone Endowed Professorship in Environmental Engineering; Professor, Civil and Environmental Engineering
Mark Modera, Associate Director, EEC; Director, Western Cooling Efficiency Center; Sempra Chair in Energy Efficiency; Professor, Civil and Environmental Engineering
Michael Siminovitch, Associate Director, EEC; Director, California Lighting Technology Center, Arthur H. Rosenfeld Chair in Energy Efficiency; Professor of Design

Key Topics

- **Activities in Lighting, HVACR, and Water Efficiency; Data**

12:05 pm **Board Photo & Lunch**

12:45 pm **Student Presentations & Update on Solar Decathlon**

1:00 pm **Discussion**

New approaches and solutions needed to leave no load left behind in achieving SB350 Efficiency Goals. The Energy Commission is charged with implementation of SB350, and preliminary indications are that they will focus efforts based on the AB 758 Action Plan released this Spring.

- What new technologies and strategies might be needed?
- How can we leverage the interest of local governments: cities, counties, and regional government entities?
- How might we leverage utilities' low cost of capital and their comprehensive distribution channel?
- Can we draw on the mandates that are now in place for C&T funds to invest in disadvantaged communities?
- How can we use data analytics and rate design to accelerate and validate investment?
- What role/activities should UC Davis be taking?

2:00 pm **Wrap-up**

2:30 pm **Adjourn**

2:45 pm **Honda Smart Home Tour (Optional)**

UC Davis West Village
1605 Tilia Street
Davis, CA

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Biographies: Board of Advisors

Ralph Cavanagh

Ralph Cavanagh is the Co-Director of the Energy Program at the Natural Resources Defense Council. He has been a Visiting Professor of law at Stanford and UC Berkeley, a lecturer on law at the Harvard Law School, and a faculty member for the University of Idaho's Public Utility Executives Course. From 1993 to 2003, Cavanagh served on the U.S. Secretary of Energy's Advisory Board. His current board memberships include the Bipartisan Policy Center, the Bonneville Environmental Foundation, the California Clean Energy Fund, the Center for Energy Efficiency and Renewable Technologies, and the Renewable Northwest Project. He is a member of the National Commission on Energy Policy, established by the William & Flora Hewlett Foundation in 2002. He received the Heinz Award for Public Policy, the National Association of Regulatory Utility Commissioners' Mary Kilmarx Award, Yale Law School's Preiskel-Silverman Fellowship, and the Lifetime Achievement in Energy Efficiency Award from California's Flex Your Power Campaign. Cavanagh is a graduate of Yale College and Yale Law School.

Robert Bienenfeld

Robert Bienenfeld is Assistant Vice President, Environment and Energy Strategy for American Honda's Product Regulatory Office. Bienenfeld is responsible for policy (legislative proposals and regulatory rule making) as it relates to the automobile and its impact on the environment. In addition, he is responsible for recommending long-term strategies to address greenhouse gas, energy security, and air quality issues. Bienenfeld was responsible for Honda's discussions with the White House that led to the historic 2012–2016 and 2017–2025 Greenhouse Gas and Fuel Economy Regulations. Bienenfeld is a 30+ year Honda veteran. Key accomplishments include: the initial proposal for Honda's "Safety for Everyone" strategy, Honda's introduction of telematics, Honda's investments in car sharing, and vehicle refueling technologies. Bienenfeld led the launch of Honda's first battery electric car, the 1997-9 EV PLUS, Honda's first generation Civic natural-gas vehicle (1998), and the original Honda Insight (1999). Bienenfeld graduated from St. John's College.

Elisabeth Brinton

Elisabeth S. Brinton is Vice President, Corporate Strategy for Pacific Gas and Electric Company. Brinton joined PG&E in the fall of 2014 and is responsible for corporate strategy and corporate development. Most recently, she was Executive Vice President of Operations for C3 Energy. Prior to that, Brinton was Chief Customer Officer for SMUD, where she ran the vertically integrated utility's $2 billion retail business. Earlier, Brinton was a senior executive in three successful startups, and was also founder and CEO of her own company in Silicon Valley, BPR, which she grew and successfully sold. Out of college, she worked on Capitol Hill for a member of Congress and for the House Judiciary Committee, staffing both environmental and energy policy issues. Brinton holds three bachelor's degrees from Principia College, is a Harry S. Truman Scholar, and a graduate of Singularity University's Global Executive Program. Brinton now serves as the co-chair for Singularity University's Energy and Climate Program.

Kathleen Hogan

Kathleen Hogan is Deputy Assistant Secretary for Energy Efficiency in the Office of Energy Efficiency and Renewable Energy at the U.S. Department of Energy. She oversees energy efficiency policy, program, and research portfolios including industrial, building, and vehicle technologies, along with federal energy management. Hogan served for more than 10 years as a division director at U.S. EPA and was responsible for the development and operation of EPA's clean energy programs, focused on removing market barriers for energy efficiency and renewable energy. These programs included the ENERGY STAR® program; programs for combined heat, power and renewable energy; corporate leadership programs; and efforts focused on state clean energy policies. She has been recognized for her work with a Presidential Rank Award, induction into the Energy Efficiency Hall of Fame of the U.S. Energy Association, and as a contributor to the Nobel Peace Prize awarded to the Intergovernmental Panel on Climate Change. Hogan holds a Ph.D. from Johns Hopkins University and a bachelor's degree from Bucknell University.

Nicole Howard

Nicole Howard was appointed Chief Customer Officer at the Sacramento Municipal Utility District (SMUD) in February 2015. Reporting to the chief executive officer and general manager, Howard runs SMUD's $1.5 billion retail electric business, including customer operations, services, and programs such as energy efficiency and advanced energy solutions. Her role includes corporate strategy, brand marketing, communications, and economic and community development. In her 12 years with SMUD, Howard has held a variety of positions. Most recently, she served as SMUD's Customer Services Director. Howard currently sits on the Board of the Cosumnes River College Foundation and represents SMUD on the Western Energy Institute's Women in Energy Planning Committee. She holds a bachelor's degree in legal studies from UC Berkeley and a master's degree in public administration from CSU, Dominguez Hills. In addition, she is a graduating Fellow of the Nehemiah Emerging Leaders Program and the Catalyst Leadership Program.

David Jacot

David Jacot, P.E., is the Director of Energy Efficiency for the Los Angeles Department of Water & Power (LADWP). In this role, Jacot oversees all aspects of LADWP's offerings and strategies designed to overcome market barriers to the comprehensive adoption of energy efficiency by LADWP's customers. He has a Bachelor's degree in Mechanical Engineering from the University of Oklahoma, and a Master's degree in Urban and Regional Planning from California State Polytechnic University - Pomona, as well as 15 years of experience designing high performance building systems, modeling building energy usage, and managing cost-effective and investment-grade energy efficiency programs.

Biographies: Board of Advisors

Bret Lane

Bret Lane is the Chief Operating Officer for Southern California Gas Company (SoCalGas), a Sempra Energy California regulated utility, and the largest natural gas utility in the US. Lane Oversees all activities related to the delivery of natural gas services to the 20 million consumers served by SoCalGas. Prior to becoming COO, Lane served as senior vice president of gas operations and system integrity for SoCalGas, responsible for all aspects of gas delivery services, including region operations, engineering, transmission, storage, and pipeline safety. He has held several other senior level positions with SoCalGas, including vice president of gas transmission and distribution, vice president of field services, vice president of environmental safety and facilities, vice president of labor relations, and was Chief Environmental Officer. Lane holds a bachelor's of science degree in petroleum engineering from Oklahoma State University.

Dan'l Lewin

Dan'l Lewin is a Corporate Vice President at Microsoft, leading the company's work in civic technology, including campaign technologies, environmental sustainability, policy-oriented academic outreach, and university relations. Previously, he led the company's global engagement with startups and venture capitalists, and business relationships with strategic industry partners. Lewin reports to Microsoft President Brad Smith and also has executive and site responsibility for the company's operations in Silicon Valley. Lewin has spent more than 30 years as a Silicon Valley-based executive, leading sales and marketing divisions for companies including Apple Computer Inc., NEXT Inc., and GO Corp. Before joining Microsoft in 2001, he was CEO of Aurigin Systems Inc. Lewin serves on the boards of the Silicon Valley Community Foundation, World Business Chicago, and UI LABS. He is also on the Advisory Council for the Department of Politics at Princeton University. Lewin holds an AB in politics from Princeton University.

Wesley Lohec

Wesley E. (Wes) Lohec is vice president, Health, Environment, and Safety for Chevron Corporation, a position he has held sine 2011. He is responsible for leading health, environment, and safety strategic planning and issues management; compliance assurance; and emergency response. He is also responsible for Chevron's Environmental Management Company, which manages environmental remediation and abandonment liabilities. Previously, Lohec served as managing director of the Latin America strategic business unit, from 2008 to 2011, for Chevron Africa and Latin America Exploration and Production Company in Caracas, Venezuela. He joined Chevron in 1981 as a drilling engineer and has held a number of positions with increasing responsibility in drilling, production engineering, operations, human resources, asset management, and business planning. Lohec is a member of the Society of Petroleum Engineers and is a registered professional engineer in the state of Texas. He earned a bachelor's degree in petroleum engineering from Texas A&M University.

Amory B. Lovins

Amory B. Lovins is a consultant experimental physicist, author, and visionary in the fields of energy and resource efficiency, environmental policy, and security policy. He co-founded and currently serves as Chairman and Chief Scientist at Rocky Mountain Institute, a non-profit, independent, think-and-do tank that creates abundance by design. He is a member of the Advisory Board to the Chief of Naval Operations and of the National Petroleum Council. In 2009, *Time* named him one of the world's 100 most influential people, and *Foreign Policy*, one of the 100 top global thinkers. He has authored or co-authored 29 books and hundreds of papers, including "Natural Capitalism" and "Winning the Oil Endgame." His work has been recognized by a MacArthur Fellowship, a Time Hero for the Planet Award, and the Blue Planet and Volvo Environment prizes.

Barry Neal

Barry Neal is the Executive Vice President leading Wells Fargo's Environmental Finance activities, and managing a group whose primary focus is originating lending and investment opportunities in the renewable energy sector. His scope of activities is borne out of Wells Fargo's Environmental Commitments, first announced in 2005 and then expanded in 2012. These commitments include a focus on providing capital to environmentally-beneficial businesses and projects in several industry sectors including renewable energy, cleantech, energy efficiency, and real estate. Neal joined Wells Fargo in 2006, after spending more than 20 years in the energy and environmental sectors. Prior to joining Wells Fargo, he provided management consulting services to financial institutions and renewable energy development companies. Neal earned a M.S. in Energy Management & Policy from the University of Pennsylvania and a B.S. in Business Administration from the University of California at Berkeley.

Kevin Payne

Kevin M. Payne is Senior Vice President of Customer Service for Southern California Edison (SCE). He is responsible for SCE's demand-side management programs, customer products and services, customer engagement and call center operations, field services, account management, and advanced metering. Prior to his current role, Payne was vice president of Engineering & Technical Services for SCE, overseeing the planning, engineering and designing of SCE's transmission and distribution systems. Payne has held various leadership positions within SCE. He began his career with SCE in 1986 in the Engineering and Construction department managing power plant retrofit and other engineering projects. Payne has a degree in mechanical engineering from the University of California, Berkeley and is a registered professional engineer.

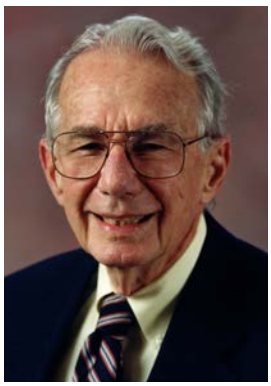
Biographies: Board of Advisors

Michael R. Peevey

Michael R. Peevey retired from the California Public Utilities Commission, where he served as President, at the end of his term in December, 2014. He is spending more time with his family while he writes a book on California energy-environmental policies over the past 40 years. Peevey was appointed President of the Commission by Gov. Gray Davis in 2002. From 1995 until 2000, he served as President of NewEnergy, Inc. Earlier, Peevey was President of Edison International and Southern California Edison. He has served on many boards and has received numerous awards recognizing his leadership in developing energy policy and promoting recognition of California's diverse population. He has received leadership recognition from the American Council for Energy Efficiency (2005), the Utility Minority Access Program (2006) and the California Solar Energy Industries Association (2006). He holds bachelor's and master's degrees in economics from the University of California, Berkeley.

Nancy Pfund

Nancy Pfund is Founder and Managing Partner of DBL Partners (formerly Investors), a venture capital firm whose goal is to combine top-tier financial returns with meaningful social, economic, and environmental returns in the regions and sectors in which it invests. She currently sponsors or sits on the board of directors of several companies, including SolarCity (NASDAQ: SCTY), where she is Chair of the governance committee and sits on both the audit and compensation committees; Primus Power; Powergenix; Farmers Business Network; The Muse and Off-Grid Electric; and, prior to their public offerings, Tesla Moters and Pandora Media. Prior to founding DBL, Pfund was a Managing Director in Venture Capital at JPMorgan, having started her investment career at Hambrecht & Quist in 1984. She holds bachelor's and master's degrees from Stanford University and a master's degree from the Yale School of Management.



Arthur H. Rosenfeld

Arthur H. Rosenfeld received his Ph.D. in physics at the University of Chicago under Nobel Laureate Enrico Fermi, and then joined the Department of Physics at UC Berkeley. He later led the Nobel Prize-winning particle physics group of Luis Alvarez at Lawrence Berkeley National Laboratory. At that time, he changed his research focus to the efficient use of energy, and formed and led the Center for Building Science at LBNL. He was appointed to the California Energy Commission by two governors. Rosenfeld was responsible for the Public Interest Energy Research program, with an annual budget of $82 million; for energy efficiency, including the California energy efficiency standards for buildings and appliances; for collaborating with the Public Utilities Commission Proceeding on demand response, critical peak pricing, and advanced metering; and the Proceeding on Energy Efficiency Programs, with an annual budget of $600 million. He is author or co-author of nearly 400 refereed publications, received the Szilard Award for Physics in the Public Interest, the Carnot Award for Energy Efficiency from the U.S. Department of Energy, and the Berkeley Citation. He also received the Enrico Fermi Award, the oldest and one of the most prestigious science and technology awards given by the U.S. government.

Mark Vanderhelm

Joining Walmart in 2015, as Vice President for Energy, Mark Vanderhelm leads the team supporting Walmart U.S., including Retail Energy, Energy Regulation and Management, Energy Services, and Energy Development. He oversees the company's global commitment to energy efficiency, sustainability, and renewable energy. Vanderhelm joins the company from Exelon Generation, LLC in Pennsylvania, where he managed Generation and Renewables Development. In this role, he led the team responsible for developing new generation projects (gas, solar, biomass, storage, and hydro) and investing in new electricity-based technologies throughout the U.S. and Canada. Vanderhelm holds a bachelor's degree in Mechanical Engineering from University of Texas and a master's degree and doctorate in Nuclear Engineering from MIT, where he co-directed the Institute of Nuclear Power Operations' Reactor Technology Course for Utility Executives.

Caroline Winn

Caroline Winn is Chief Energy Delivery Officer for San Diego Gas & Electric (SDG&E), one of Sempra Energy's regulated California utilities. Winn oversees all energy delivery activities for SDG&E, including electric distribution operations and gas services, customer services, and external and state legislative affairs. Since joining the company, she has held a number of leadership positions with SDG&E and Southern California Gas Company. Prior to her current position, Winn was vice president of customer services and chief customer privacy officer. Winn has a bachelor's degree in electrical engineering from California State University, Sacramento and is a registered professional engineer in the state of California.

Biographies: Special Guests

Jeanne Clinton

Jeanne Clinton is special advisor to the California Public Utilities Commission. She is responsible for identifying innovations in policy, legislative, and utility funding strategies to double the pace of energy efficiency. Clinton has been a manager of the Climate Strategies Branch of the Commission since 2009. She was an advisor on clean energy and policy planning to the Commission from 2006 to 2009 and a consultant to former California Energy Commissioner, Jackalyne Pfannenstie, from 2005 to 2006. Clinton served as an international energy efficiency advisor for the Vietnam Ministry of Industry from 2004 to 2005 and deputy director for the California Consumer Power and Conservation Financing Authority from 2001 to 2004.

Walt Di Mantova

Walt Di Mantova has over twenty years of experience in developing, managing and directing innovative corporate and workforce training initiatives in partnership with some of the country's largest corporations. Since 2003 he has served as the Director of Workforce and Economic Development for Los Rios CC District in Sacramento leading their efforts supporting government, small and large businesses. Previously he was the District's Director of Contract Education. Prior to his work with Los Rios, Di Mantova was Director of the Centers for Corporate Training at Eastern Michigan University, which served over 10,000 people per year across the US and in eleven different countries. He had authored several articles on quality in education and was a Fellow of the University College, University of London, England. Di Mantova received his B.A. from the University of Colorado, Boulder and his M.A. from the University of Michigan.

Bernie Kotlier

Bernie Kotlier is the executive director of Sustainable Energy Solutions for the California Labor Management Cooperation Committee (LMCC), a joint effort of the National Electrical Contractors Association, and the International Brotherhood of Electrical Workers in California. He is responsible for the development and implementation of sustainable energy education and training programs, as well as related sustainable energy business activities. Kotlier has also contributed to the development of California state energy policy and programs. He has been a member of the California Public Utilities Commission Advisory Committee on Sustainable Energy Workforce Development, the Zero Net Energy Advisory Committee, the Working Group on Lighting, and the State of California Schools of the Future Initiative Advisory Committee. Kotlier co-founded and serves as co-executive chairman of the California Advanced Lighting Controls Training Program and co-chairs the national Electric Vehicle Infrastructure Training Program.

Lifang Chiang

Lifang Chiang is Manager in the Office of the Vice President-Research, University of California Office of the President. Her responsibilities include project management, program and budget evaluation, and coordination of systemwide research initiatives. Prior to her current position, Chiang was Coordinator of Academic Planning and Programs in the University of California Office of the President; a Supervisory Management Analyst at the U.S. Department of Labor; and an Instructor in Health Economics at the University of California, San Francisco. She received her B.A. in Political Science, Master of City Planning/Master of Public Health, and Ph.D. in Economic Geography from the University of California, Berkeley.

Ken Rider

Ken Rider is an associate electrical engineer and advisor to Commissioner Hochschild at the California Energy Commission. Prior to his current position, Rider was a researcher at the Center of Biophotonics Science and Technology. He received a B.A. in electrical engineering from UC Davis.

Ian Rogoff

Ian Rogoff is Executive Chairman of HelioPower, an integrated energy solutions company and its affiliated companies, Helio Energy Solutions and Helio Micro Utility. He is an active investor in software and renewable energy fields, serving as Co-Founder and General Partner at Sierra Nevada Partners, an investment management company established to buy and grow sustainable businesses located in the Western U.S. Rogoff serves as Chairman of the Nevada Institute for Renewable Energy Commercialization, a non-profit public-private partnership that integrates researchers, experienced entrepreneurs, business executives and venture capital to identify and fund viable renewable energy solutions. He has diverse industry experience including software, discrete manufacturing, aerospace and energy. Rogoff holds a B.S. in electrical engineering from the University of Miami, a M.S. in Industrial Engineering from The Georgia Institute of Technology, a M.A. from Stanford University, and has completed an executive management program at Dartmouth College.

Biographies: Faculty Leadership

Frank J. Loge

Frank Loge is Director of the UC Davis Center for Water-Energy Efficiency (CWEE) and Professor and Vice Chair of Graduate Studies, Department of Civil and Environmental Engineering and holds the Krone endowed professorship in Civil and Environmental Engineering. He is working to bridge the chasm between civil engineering and information technology to build a modern information architecture that enables intelligent water production, treatment, delivery, consumption, and post-treatment. Loge also serves on the City of Davis Water Advisory Committee and co-authored Davis's novel consumption-based fixed-rate water rate structure, which sends consumers a strong, fair conservation signal with revenue stability for water utilities. Loge holds a Ph.D. in civil and environmental engineering from UC Davis.

Mark Modera

Mark Modera is the UC Davis Sempra Energy Chair in Energy Efficiency, Director of the Western Cooling Efficiency Center (WCEC), Professor in Civil and Environmental Engineering, and Professor in Mechanical and Aerospace Engineering. He was president of Aeroseal, Inc., a business he founded to commercialize a technology he developed at Lawrence Berkeley National Laboratory (LBNL). When Aeroseal was purchased by Carrier Corporation, Modera served as general manager and later vice president of strategic operations. He spent 25 years as a staff scientist at LBNL. His research interests include energy efficiency, ventilation, and indoor air quality. Modera holds a master's degree from the University of California, Berkeley and a Ph.D. in mechanical engineering from the Royal Institute of Technology in Stockholm.

Michael Siminovitch

Michael Siminovitch is Director of the UC Davis California Lighting Technology Center (CLTC), Professor of Design, and the Rosenfeld Chair in Energy Efficiency. His work entails research and development in new residential and commercial lighting technologies. Siminovitch was part of the development team for California's Strategic Lighting Plan and helped lead efforts to update the state's latest Title 24 and Title 20 regulations for exterior lighting. He also helped establish the UC Davis Smart Lighting Initiative, one of the largest lighting retrofit projects in California, as a model strategy for the UC system and other institutions. Siminovitch has developed many successful lighting products, such as the Berkeley Lamp, which uses one-quarter the wattage of traditional lamps. He has also developed an innovative fluorescent down-lighting system for commercial and residential spaces, high performance torchiere, high efficiency sulfur lamp, and fiber optic illuminators. He holds a Ph.D. in architecture and human factors engineering from the University of Michigan.

Andrew Hargadon

Andrew Hargadon is the Charles J. Soderquist Chair in Entrepreneurship and Professor of Technology Management at the UC Davis Graduate School of Management. He is the author of *How Breakthroughs Happen: The Surprising Truth About How Companies Innovate* (Harvard Business School Press 2003). Hargadon's research focuses on the effective management of innovation and entrepreneurship, particularly in the development and commercialization of sustainable technologies. He has published numerous articles and chapters in leading scholarly and applied publications. Hargadon's research has been used to develop or guide new innovation programs in a wide range of large organizations as well as multiple start-ups.

Kurt Kornbluth

Kurt Kornbluth is the founder and director of the UC Davis Program for International Energy Technology and the UC Davis D-Lab. He is an adjunct professor in the Department of Engineering and Biological Sciences. Kornbluth's current research areas include hybrid fossil fuel/renewable electrical grids, and sustainable, low-carbon energy technologies for the developed and developing world. He has worked in the field of international development, renewable energy, and energy efficiency since 1993 and has a diverse background including implementing appropriate technology projects in Africa and Central America. Kornbluth worked with Amy Smith at the MIT D-Lab during its inception and in 2008 created the D-Lab at UC Davis. He holds a PhD in Mechanical and Aeronautical Engineering from UC Davis and is a UC Davis Graduate School of Management Business Development Fellow as well as an NSF IGERT fellow.

Alan Meier

Alan Meier is a Senior Scientist at Lawrence Berkeley National Laboratory and teaches core energy efficiency courses and supervises graduate student activities at the UC Davis EEC. His research has focused on understanding how people (and machines) use energy and the opportunities that exist for them (and technologies) to conserve. Meier's research on "standby power use" in appliances—equal to 1% of global CO2 emissions— led him to propose an international plan to reduce standby power loss in all devices to less than 1 watt, which has now been endorsed by the G8 countries. He is editor of the journal *Energy and Buildings*, and the magazine *Home Energy*. Meier is the author of many articles and two books, "Supplying Energy through Greater Efficiency" and "Saving Electricity in a Hurry." He spent one year at Waseda University in Japan and three years at the International Energy Agency. Meier holds a Ph.D. in energy and resources from University of California, Berkeley.

Biographies: Faculty Leadership

Konstantinos Papamichael

Konstantinos (Kosta) Papamichael is a Professor in the Department of Design and the Co-Director of the California Lighting Technology Center at UC Davis. He has been working on the development of energy efficiency strategies and technologies for buildings for almost 35 years, focusing on strategies, technologies and design tools for fenestration systems, daylighting, and the integration of fenestration, electric lighting and HVAC controls. Papamichael holds seven patents and is author/co-author of more than 100 publications. He is the author of the Daylight Chapter of the Advanced Lighting Guidelines, the Chair of the IES Daylighting Committee, member of the Executive Committee and VP of communications for the US Natuonal Committee of the International Committee on Illumination, and the recipient of the 2013 IES Presidential Award. He holds an Architectural Engineering degree from the Aristotelian University of Thessaloniki, Greece, a Masters in Architecture from Iowa State University, and a Ph.D. in Architecture from the University of California, Berkeley.

Dan Sperling

Daniel Sperling is Professor of Civil Engineering and Environmental Science and Policy, founding Director of the Institute of Transportation Studies at UC Davis (ITS-Davis) and interim Director of the UC Davis Energy Institute. He is recognized as a leading international expert on transportation technology assessment, energy and environmental aspects of transportation, and transportation policy. Sperling is Executive Director of the US Department of Transportation's (USDOT) $11.2 million National Center for Sustainable Transportation. He is winner of the 2013 Blue Planet Prize from the Asahi Glass Foundation of Tokyo, which has been described as the Nobel Prize for the environmental sciences. Sperling has held numerous positions on boards and committees, and has authored 12 books and over 200 technical papers and reports. He is currently Vice Chair of the Executive Committee of the National Research Council's (NRC) Transportation Research Board (TRB) and is a board member of the California Air Resources Board.

Tom Turrentine

Tom Turrentine is Director of the California Energy Commission's Plug-in Hybrid Electric & Vehicle Research Center at the UC Davis Institute of Transportation Studies (ITS-Davis). For the past 20 years, he has studied consumer response to alternative fuels, vehicle technologies, road systems, and policies with environmental benefits. His most recent work includes "Taking Charge," California's plan for electrification of transport, and multi-year projects to study consumer use of the BMW Mini-E, Prius PHEV conversions, the Nissan Leaf, and specially designed energy feedback displays in vehicles. In the coming years, Turrentine's center will be working with car companies and power utilities on purchase and use patterns of new electric and plug-in hybrids, developing tools to advise deployment of infrastructure, integration of plug in vehicles to California's grid, and ways to restructure the cost of lithium batteries. He holds a Ph.D. in anthropology.

Biographies: Associated Faculty and Researchers

Thomas Beamish

Thomas Beamish is Associate Director of the UC Davis Energy Efficiency Center and Associate Professor of Sociology at UC Davis. He has studied innovation processes in the commercial construction/real estate industry; social and organizational response to environmental change and disaster; and how and why community movements mobilize and respond as they do to "risky" developments. What ties these diverse projects together is Beamish's theoretical fascination with the intersection of institutions, social organization, and interpretive work. His focus in each of these projects has been the collective bases for "local rationalities" -- how sensemaking emerges from the places people live, the formal and informal social relations they are embedded within, and the collective memories and cognitive models they share as a result that help to explain their actions and inactions. Beamish holds a Ph.D. from the University of California, Santa Barbara.

Giovanni Circella

Giovanni Circella is a post-doctoral researcher at the Urban Land Use and Transportation Center (ULTRANS) and the Institute of Transportation Studies (ITS) at UC Davis. He also shares his time as a research engineer at the School of Civil and Environmental Engineering of the Georgia Institute of Technology (Georgia Tech). Circella focuses on travel demand modeling, land use and transportation modeling, travel behavior research, discrete choice modeling, the impact of information communication technology on travel behavior, and the analysis of policies for sustainable transportation and energy consumption. Circella has been principal investigator for three research projects at UC Davis, and has authored many scientific papers and project reports, and has made numerous contributions to scientific conferences. He is a licensed Professional Engineer (P.E.) in Italy. He received his M.S. in Agricultural and Resource Economics from UC Davis and his Ph.D. in Transportation Planning from the Politecnico di Bari (Technical University of Bari), Italy.

Amy Jaffe

Amy Myers Jaffe is UC Davis Executive Director of Energy and Sustainability. She is a leading expert on global energy policy, geopolitical risk, strategic energy policy, corporate investment strategies in the energy sector, and energy economics. She has a joint appointment to the Graduate School of Management and the Institute of Transportation Studies (ITS-Davis). At ITS-Davis, Jaffe heads the fossil fuel component of the Sustainable Transportation Energy Pathways (NextSTEPS) program. Prior to joining UC Davis, Jaffe served as director of the Energy Forum and Wallace S. Wilson Fellow in Energy Studies at Rice University's James A. Baker III Institute for Public Policy. Jaffe is widely published, including as co-author of "Oil, Dollars, Debt and Crises: The Global Curse of Black Gold" (Cambridge University Press, 2010, with Mahmoud El-Gamal). She is a member of the Council on Foreign Relations. She holds a bachelor's degree in Near Eastern Studies and Arabic from Princeton University.

Biographies: Associated Faculty and Researchers

Katrina Jessoe

Katrina Jessoe is an Assistant Professor of Agricultural and Resource Economics at UC Davis where she specializes in environmental and energy economics. Much of her recent research focuses on consumer and firm behavior in the energy and water sectors. Some ongoing and recent research projects include the analysis of time-variant pricing programs for residential and commercial electricity consumers, and the interaction between energy and water conservation programs. These projects often involve collaborations with water and electric utilities, and state agencies. She received a BA from Princeton University and a PhD in Environmental and Resource Economics from Yale University.

Vinod Narayanan

Vinod Narayanan joined UC Davis as a Professor in the Department of Mechanical and Aerospace Engineering in March 2015. He is also the Associate Director of the UC Davis Western Cooling Efficiency Center. Prior to joining UC Davis, he was a Professor and the Welty Faculty Fellow in the School of Mechanical Industrial and Manufacturing Engineering at Oregon State University. Narayanan's areas of interest include microscale flow and heat transfer, solar thermal energy utilization, passive means to enhance thermal energy efficiency, infrared thermography methods, and thermal management. He is the recipient of one of ASEE's Air Force Research Laboratory Summer Faculty Fellowships, the NSF CAREER award, and the George Kunze prize from Texas A&M University. Narayanan is chair of the American Society of Mechanical Engineers' K-13 committee on Heat Transfer in Multiphase Systems, and chaired the ASME 2015 International Conference on Nanochannels, Microchannels, and Minichannels (ICNMM). He received his PhD from Texas A&M University.

Kevin Novan

Kevin Novan is an Assistant Professor in the Department of Agricultural and Resource Economics at UC Davis. Novan's research focuses on energy and environmental economics. Previous related projects include work estimating the pollution savings achieved by investments in renewable electricity; an analysis of the environmental impacts of bulk electricity storage; and evaluation of the energy savings achieved by residential weatherization and informational programs. He received his PhD from UC San Diego.

David Rapson

David Rapson joined the Economics Department at UC Davis in 2008. He specializes in the fields of industrial organization, energy, and environmental economics, with a focus on how to achieve efficiency in energy markets. Rapson's research includes several collaborative studies with regulated utilities and government agencies. These include the evaluation of dynamic pricing regimes, the role of information in consumer decisions, understanding the market for electric vehicles, and how each of these influence optimal climate policy. Rapson also specializes in the design and analysis of large-scale randomized field experiments. His research appears in *The American Economic Review Nature*, and other academic journals. Rapson holds an AB in economics from Dartmouth College; an MA in economics from Queen's University; and a PhD in economics from Boston University.

Christopher Simmons

Christopher Simmons, an Assistant Professor in the UC Davis Department of Food Science and Technology, specializes in energy and water efficiency in food processing. Simmons worked two years as a postdoctoral scholar at UC Davis and the Department of Energy's Joint BioEnergy Institute, researching biofuels and sustainable agriculture. Simmons' research focuses on improving energy and water-use efficiency in food processing. He is interested in improving strategies to convert leftover food residue from food processing into biofuels that can offset energy used during processing. He additionally investigates methods to use food processing wastewater for agricultural irrigation. Simmons holds a Ph.D. in biological systems engineering from UC Davis.

Aaron Smith

Aaron Smith is a Professor of Agricultural and Resource Economics at UC Davis. His research focuses on quantitative analysis of policy and prices in energy, agriculture, and the environment. Recent project topics include identifying informed traders in commodity futures markets, estimating the effects of ethanol production on agricultural and energy markets, and modeling the efficiency of the California electricity reserves market. Originally from New Zealand, he earned his PhD in Economics from the University of California, San Diego where he specialized in econometrics.

Biographies: Associated Faculty and Researchers

Edward Spang

Edward (Ned) Spang is the Associate Director of the UC Davis Center for Water-Energy Efficiency and an Assistant Professor in the Food Science and Technology Department. His research focuses on characterizing and optimizing the efficiency of linked water, energy, and food resource systems. Spang is particularly interested in applying methodologies to measure and monitor these systems and their interrelationships in high-resolution and across multiple scales. He also seeks to understand the influence of markets, innovation, and policy on the integrated food-water-energy nexus. Spang's recent publications explore mapping energy flows through water infrastructure, enhancing the conservation signal and stability of water rates, and estimating global water consumption for energy production. He earned his M.A. and Ph.D. from the Fletcher School of Law and Diplomacy, Tufts University.

Felix Wu

Felix Wu, a UC Davis professor of Computer Science, has been building prototype systems and doing "experimental" system research since 1995 to validate novel architectural concepts. He has worked in the areas of fault tolerant network, IPSec/VPN security policy, attack source tracing, wireless network security, intrusion detection and response, visual information analytics, and, more recently, future Internet design. Wu strongly believes that considering the factor of human relationships is necessary for any IT innovation. Therefore, his primary research objective is to help and contribute to information technology advancement that will help human society. Wu recently released the SINCERE (Social Interactive Networking and Conversation Entropy Ranking Engine) search engine, which helps our Internet society to discover "interesting/unusual" discussions. Wu received his BS from Tunghai University, Taiwan, and his MS and PhD from Columbia University, all in Computer Science.

Benjamin Finkelor

Benjamin Finkelor is Executive Director of the UC Davis Energy Efficiency Center. Prior to joining the EEC, he served in a variety of roles within the clean technology sector, including director of business development for a local clean-energy start-up company, interim executive director for CleanStart (a Sacramento-based business incubator supporting local clean energy technology ventures and entrepreneurs), and as a clean-tech analyst for the private equity arm of the California Public Employees' Retirement System (CalPERS). He is secretary to the board of the Renewable Energy Institute International. He holds a master's degree in business administration from the University of California, Davis Graduate School of Management. He also earned an emphasis in corporate environmental management through the Bren School at University of California, Santa Barbara.

Katherine Bannor

Katherine Bannor is the Project Manager for the Energy Efficiency Center where she is responsible for assisting with grant management and coordination. She previously held the position of Executive Analyst for the Center. Prior to her work with the EEC she worked for the National Endowment for Democracy in Washington, DC in their Government Relations and Public Affairs office. She holds a Bachelor's degree in Political Science and French from Beloit College and a Master's degree in Geography from Rutgers University.

Katharine Batten

Katharine (Kit) Batten is the Executive Director for the Policy Institute for Energy, Environment and the Economy. In 2011, Batten was appointed by President Barack Obama to serve as global climate change coordinator, responsible for worldwide climate change mitigation and adaptation projects for the U.S. Agency for International Development (USAID). Prior to USAID, she served as a senior science and policy fellow and program director at the H. John Heinz III center for Science, Economics, and the Environment; as a science advisor to the deputy secretary of the U.S. Department of the Interior; and as a senior fellow/managing director for energy and environmental policy at the Center for American Progress. Batten also held positions in the offices of Senator Dianne Feinstein (D-CA) and Senator Joseph Lieberman (I-CT). Batten earned a bachelor's degree in chemistry from Oberlin College and master's and doctoral degrees in ecology from UC Davis.

Biographies: Staff

Christie Farrell

Christie Farrell is the Analyst for the Energy Efficiency Center. Her responsibilities include: developing agendas for visiting executives, scholars, and students; drafting a wide range of correspondences; and assisting with various graphic design projects. Prior to her Analyst position with the EEC, she was involved in the EEC Intern Development Program. She holds a Bachelor's degree in Design from the University of California, Davis.

Siva Gunda

Siva Gunda is a Program Manager at the UC Davis Energy Efficiency Center. He oversees all the student projects at the Center and runs the Market Assessment Assistance Program (MAAP). Prior to joining the EEC, he worked at General Electric, California Fuel Cell Partnership, and the California Air Resources Board. He has been an Edison International Energy Efficiency Fellow and a UC Davis Center for Entrepreneurship Business Development Fellow. Gunda was a winner in the 2007/08 Little Bang business plan competition. He is a UC Davis PhD candidate in Mechanical and Aeronautical Engineering with a focus on alternate energy systems. His research focus is on enhancing the performance of PEM fuel cells.

Kristin Heinemeier

Kristin Heinemeier recently joined the UC Davis Energy Efficiency Center as Principal Engineer. Identifying ways to realize efficiency in the real world has been her life's work, with a 30 year portfolio of positions at national labs, academia, private industry, non-profit organizations, and local government and community-based organizations. Heinemeier is currently founder and facilitator of the EEC Realized Energy Solutions Collaborative. In addition, she was one of the founders of the Western HVAC Performance Alliance. In January 2016, Heinemeier will be awarded the distinction of becoming an ASHRAE Fellow. She received her Ph.D. in building science from the University of California, Berkeley and is a licensed Mechanical Engineer.

Taimour Khalid

Taimour Khalid has been with EEC since winter 2013 and is currently working on a Multi-Tenant Light commercial project. Khalid previously worked at Morgan Stanley in Sacramento as a Financial Trainee. Before coming to the United States, he worked in Pakistan at McDonald's Corp. as a sales and marketing intern, and as a sales intern at Pak Elektron Limited, an appliances manufacturing company. Khalid holds a bachelor's degree in Economics and Statistics.

Joe Krovoza

Joe Krovoza is Senior Director for Development and External Relations for the UC Davis Energy Efficiency Center and Institute of Transportation Studies (ITS-Davis). In this capacity he oversees both institutes' public affairs, and works with companies and government agencies that support the EEC and ITS-Davis through partnerships, including contributions in support of faculty research and multi-party Institute research consortia. These programs include major energy and environmental transportation research initiatives such as the ITS-Davis Plug-in Hybrid & Electric Vehicle (PHEV) Research Center, Sustainable Transportation Energy Pathways (STEPS) program, and China Center for Energy and Transportation (C-CET). Krovoza holds a juris doctor degree from the UC Davis School of Law and a bachelor's degree from Occidental College in diplomacy and world affairs and economics.

Alicia Loge

Alicia (Ali) Loge is Senior Writer for the UC Davis Energy Efficiency Center. She is responsible for writing, editing, and producing print and online materials for audiences in academia, government, industry, and the general public. Prior to joining the EEC, Loge was a consultant for the Children and Nature Network, a graduate student and researcher at Yale University, and a communications program manager for the National Oceanic and Atmospheric Administration's Northwest Fisheries Science Center. Loge holds a master's degree in environmental health and sustainability from the Yale School of Forestry and Environmental Studies and a bachelor's degree in biology from Smith College.

Biographies: Staff

Adam Schultz

Adam Schultz joined UC Davis in January 2014 as the Program Manager of the UC Davis Energy Institute where he has focused on expanding interdisciplinary research efforts on energy supply issues, while also leading the effort to develop and secure approval of an Energy Graduate Group at UC Davis. The Energy Graduate Group, expected to receive final approval as early as mid-2016, would award M.S. and Ph.D. degrees in one of two tracks: (1) Energy Science & Technology, and (2) Energy Policy & Management. Schultz has also collaborated with the EEC on issues related to the integration of efficiency measures and renewable energy at the community-scale. Prior to joining UC Davis, he was a Senior Analyst at the California Public Utilities Commission in San Francisco, where he led the development and oversight of California's wholesale renewable distributed generation procurement programs. He also spent time working on energy issues in the US Senate as a legal fellow for Senator Ron Wyden of Oregon. Schultz graduated with a B.A. in Political Science from Tufts University and a J.D. from the Benjamin Cardozo School of Law at Yeshiva University.

Nancy Skinner

Nancy Skinner is the Senior Policy Fellow for the UC Davis Energy and Transportation Programs, which include the Energy Efficiency Center, Institute of Transportation Studies, and the Policy Institute for Energy, Environment and the Economy. She is a former three-term state Assemblymember who began her public service in 1984 as the first and only UC Berkeley student to be elected to the Berkeley City Council. As a councilmember from 1984-1992, she established the Berkeley Energy Services Corporation and the city's commercial and residential energy upgrade ordinances. Skinner represented the East Bay's 15th District from 2008-2014 and served as chair of the Natural Resources, Rules, and Budget committees. She authored dozens of laws with energy-focused legislation that included an expansion of incentives for solar customers, energy storage initiatives, and building energy efficiency requirements. Skinner is a graduate of UC Berkeley, earning a bachelor's of science degree from the College of Natural Resources and a master's degree in education.

Enrique Ybarra

Enrique Ybarra is the Assistant Project Manager for the UC Davis Energy Efficiency Center's Proposition 39 work. He joined the EEC in February of 2014 as a student intern, and joined as full-time staff upon his graduation. He holds bachelors' degrees in both Economics and History from UC Davis.

Update: California Lighting Technology Center

The California Lighting Technology Center (CLTC) continues its commitment to stimulate, facilitate, and accelerate the development and commercialization of energy-efficient lighting and daylighting technologies. Some notable accomplishments in 2015 are highlighted below.

Investing in California communities through building energy efficiency workforce development

CLTC's newest efforts showcase a continuing commitment to improving energy efficiency education in California and beyond. CLTC, in partnership with the Center for Sustainable Energy (CSE) and the California IBEW-NECA Labor Management Cooperation Committee (CA LMCC), is working to expand career pathways in the electrical industry. With new funding from the California Energy Commission, CLTC will develop training resources to increase workforce development opportunities in disadvantaged communities. The new program will provide apprentices with the skills needed to install and maintain grid-connected automated demand response (ADR) communication equipment. This technology is critical to meeting California's energy efficiency targets and the goals of AB 32 and AB 758. CLTC will support development of ADR laboratory training materials, exercises, and training boards for Joint Apprenticeship Training Centers in California.

The California Community Colleges (CCC) and the project team at the University of California have also collaborated on a shared initiative to improve and advance energy efficiency workforce development to meet industry standards and employer needs in the clean energy economy.

> Cultivating a skilled, diverse workforce dedicated to advancing the energy efficiency of California's existing buildings is critical to growing the statewide clean energy economy, and ensuring that advanced technologies—like lighting controls and automated demand response communication equipment—operate and perform correctly.

A majority of incumbent workers are not trained on energy efficiency, and even those that have such training are faced with frequent changes in technology, codes, and standards. This effort is focused on identification of opportunities for improving CCC curriculum and instructor knowledge with respect to lighting and energy efficiency. Recent activities include development of a detailed inventory and characterization of existing CCC curriculum to identify promising programs and potential pathways to advance energy-efficiency education in the CCC system.

Advancing Lighting Controls Education Through CALCTP

CLTC continues to support and enhance the California Advanced Lighting Controls Training Program (CALCTP). CLTC collaborates with CALCTP as the subject-matter expert technical curriculum developer for the program. CALCTP provides training and certification to electricians, contractors, acceptance test technicians, building operators, and managers. The program is increasing the use of energy-saving lighting controls in commercial buildings and ensuring they are properly installed and commissioned for maximum effectiveness.

CLTC provides expertise for lighting and lighting controls training programs across California.

CLTC maintains and expands the training curriculum, keeping CALCTP current with lighting technology and best practices. The program includes intensive, hands-on laboratory work that allows students to practice the technical skills they will need in the field. To date the program has successfully trained and certified more than 2,200 electricians and 90 electrical contractors, statewide. It has nearly 100 trained instructors teaching at 32 training centers throughout the state, including utility training centers, California Community Colleges, and electrician apprenticeship training centers.

The CALCTP training curriculum is comprised of three different programs: 1) Installers, 2) Acceptance Test Technicians, and 3) Building Operators.

Looking Ahead To A Zero-Net Energy California

California has established an ambitious goal that by 2020, all new residential homes will meet ZNE targets and produce at least as much energy as they consume. This means that all new homes must operate more efficiently than existing homes, and include energy generation capability such as solar photovoltaics (PV). To support California's transition to ZNE, CLTC is working with developers, utilities and manufactures to deliver energy-efficient lighting products, design services and education targeted at ZNE readiness. Recent activities include development of a ZNE Display Home in collaboration with Pacific Gas and Electric Company. The project will showcase the effectiveness, efficiency, value, and financial accessibility of various ZNE technologies and tools and how they can be integrated in an everyday home.

CLTC's 2013 Title 24, Part 6 lighting guides provide a resource for builders and lighting industry professionals to become more familiar with California's 2013 Building Energy Efficiency Standards. Photo: Kathreen Fontecha

CLTC has also partnered with developers of the Liberty Community, a ZNE community in West Sacramento along the Sacramento River, on the Liberty Sustainable Lighting Initiative. The most recent outcome of this initiative, the Liberty Lighting Guide, provides design and technical specifications, application of directives, as well as Title 24 code compliance requirements for residential, outdoor, private community clubhouses, K – 8 schools, private clubhouses, neighborhood commercial spaces, parks, greenbelts, trails, sports, and recreation centers.

In addition, CLTC's popular lighting application guides were updated and released earlier this year. These guides are designed to assist building industry professionals with meeting or exceeding California's Building Efficiency lighting standards. The 2013 Title 24, Part 6 lighting guides for office, retail, and outdoor applications were created to help people navigate updates to the nonresidential portion of the building standards. The residential and high-efficacy residential lighting guides help those working on sustainable and ZNE residential projects. The guides were selected for inclusion in the Illuminating Engineering Society's annual Progress Report and were featured at the IES Annual Conference in Indianapolis, IN, on November 9, 2015.

From the Lab to the California Marketplace—A New Generation of LED Lighting Solutions

Widespread adoption of LED lighting for general illumination applications is poised to be the single largest advancement in lighting efficiency during the 21st century. Due to its potential, a variety of market actors have introduced LED products, and made associated performance claims, that have set the technology up with somewhat unrealistic expectations regarding system efficacy and longevity. To compete in this market, LED manufacturers have focused on research with

CLTC is working with industry professionals to develop a new generation of LED lighting solutions. Photo: Molly Schellenger

respect to efficacy improvements and cost reductions at the expense of product quality and feature optimization.

CLTC is collaborating with lighting industry partners Go Green LED, Green Creative, Cree, Inc., and Finelite to design and develop novel LED lighting that addresses quality targets as well as energy efficiency. CLTC research and development will focus on a best-in-class medium, screw-base replacement lamp; a linear LED replacement lamp; and spectrally optimized, dedicated LED luminaire. Once commercially available, each will lead to sustained electricity savings for California ratepayers.

This research project will address consumer-optimized design as a means to improve product performance, consumer satisfaction, and sustained use of LED solutions. Results will also be used to further understanding of lamp characteristics that may limit market acceptance of LED technology, and identify performance gaps that must be addressed to achieve deep energy savings in the commercial and residential building sectors. In addition, research outcomes regarding customer preference for lighting attributes will be available to all lighting manufacturers so that they can capitalize on and incorporate product features that consumers will want and embrace.

Quality Lighting—CLTC's LED Lamp Testing Program

Expanding on 2013-2014 efforts, CLTC researchers are working with California's investor-owned utilities to widen the scope of LED lamp testing to include additional lamp types such as MR-16 lamps and G-24 four-pin lamps. The LED Lamp Performance Testing Program's goal is to help utilities and others understand how the lamp market is changing and identify which lamps meet performance thresholds.

MR-16 LED Lamp Testing—While the energy savings associated with the switch from halogen to LED is easy to see, actual product performance may be less clear-cut. Consumers have experienced performance issues, including visible flicker and audible humming, which have been linked to the use of the LED lamps with certain types of electrical components, including some types of dimmer switches and low-voltage transformers.

To help better understand the current state of these products and potential performance issues, CLTC evaluated a cross-section of commercially available LED MR16 lamps, the most common type of MR lamp, to better understand the product's compatibility with electrical components designed for use with traditional halogen sources. Researchers conducted performance evaluations of 20 commercially available LED MR16 lamps operated in conjunction with multiple types of

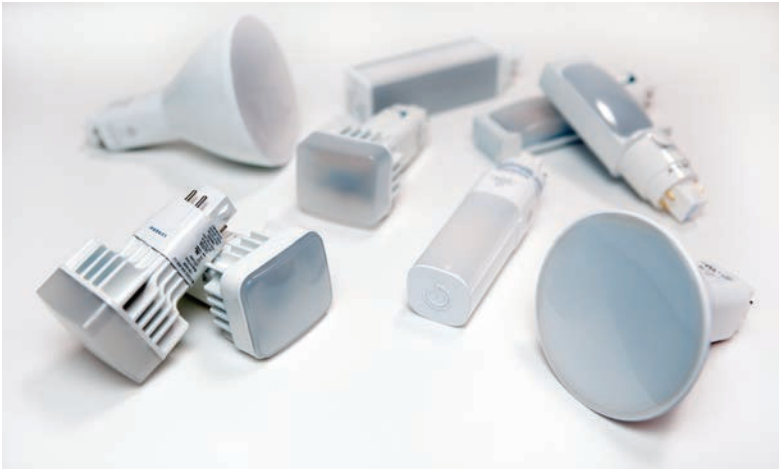
low-voltage transformers, LED drivers, and dimmer switches. The primary study objective was to identify links between poor lamp performance, specific LED driver designs, and other standard electrical components. The final report was prepared for PG&E and may be found online at http://cltc.ucdavis.edu/publication/201505-electrical-compatibility-mr16-led-replacements.

Residential Upstream Lighting Program—CLTC is now the lead organization conducting LED product evaluations for the Upstream Residential Lighting Incentive Programs offered by the California Investor Owned Utilities. Program requirements are based, in large part, on the California Voluntary LED Quality Specification, championed by CLTC in 2012, and adopted by the California Energy Commission in 2013. CLTC works with utility program managers to identify suitable products, evaluate samples, and assist manufacturers with program compliance. More information on this program may be found at http://cltc.ucdavis.edu/ca-iou-program-led-manufacturer-overview.

Defining Accuracy—Energy Use Reporting through Lighting Control Systems—One of the promises of networked lighting controls is the ability to monitor lighting energy use over time and adjust the system to achieve the best possible performance. Facility managers can match system use to expectations and change settings to capture maximum savings. The promise of real-time energy monitoring has also piqued the interest of utility program managers in locations in the U.S. where rebates assist with the accelerated adoption of emerging technologies.

One of the promises of networked lighting controls is the ability to monitor lighting energy use over time and adjust the system to achieve the best possible performance.

CLTC, in collaboration with Sempra Utilities, developed a test methodology to evaluate the accuracy and reliability of onboard metering and system reporting features of advanced lighting control systems (ALCS). The project team applied the procedure to three commercially available ALCS in order to refine the methods and help the utility determine if such features were currently reliable and accurate enough to substitute for the independent and expensive collection of sub-metered data, often required to calculate project savings and associated financial rebates. National ratings systems, such as LEED, may also consider and reward long-term performance on a more verifiable basis. The final report was prepared for SDG&E and may be found online at http://cltc.ucdavis.edu/publication/201506-advanced-lighting-control-systems-bench-testing.



CLTC's LED Lamp Perfomance Testing Program now encompasses MR-16 lamps and G-24 four-pin based lamps, along with LED replacement A-lamps. Photo: Betty Chen

Update: Western Cooling Efficiency Center

The Western Cooling Efficiency Center (WCEC) is reshaping the landscape of opportunity for energy efficient building systems. The Center is challenging long-standing precedents, and exploring solutions that promise dramatic savings. This is an exciting time. Technology is evolving rapidly and WCEC is working closely with industry affiliates to forge a strategic path forward. Together, we are developing a broad range of solutions, including new and sometimes unconventional perspectives about the future of thermal energy systems in buildings.

WCEC's portfolio of work includes projects that span many diverse and unique skillsets, including product benchmarking and improvements, behavioral factors in efficient HVAC acceptance, advocacy, first principles research, modeling, and building energy management systems. In addition to these broad industry and policy support roles, the Center also creates new technologies. Our home-grown envelope sealing technology was just recently licensed by the company Aeroseal for both sealing building envelopes and low-flow gas pipelines. Some notable accomplishments in 2015 are:

Welcoming a New Financial Coordinator

The WCEC is proud to announce the latest member of our team, Maria (Maru) Fernandez. Maru is the Financial Coordinator for the WCEC. She holds a B.S. in Entrepreneurial Management and Marketing from the Wharton School of Business at the University of Pennsylvania. Maru's professional career began with the transformation and expansion of her family's retail chain in Puerto Rico. She specialized in product design and in building successful business relationships with manufacturers from Spain, Mexico, Colombia, Brazil, Chile, and Argentina. Prior to working at the WCEC, Maru was the Admissions and Recruiting Coordinator of the International English and Professional Programs at UC Davis Extension. At WCEC, Maru is responsible for highly technical financial support for the Center, including budgetary planning and extramural fund analysis.

Maria (Maru) Fernandez, WCEC's new Financial Coordinator.

Reaching Out to a Wide Audience

- Mark Modera Chaired session 90.1 on Evaporative Pre-Cooler protocol design at ASHRAE in Chicago and Atlanta.
- Provided numerous meetings and tours for industry stakeholders including Trane, Daikin, Honeywell, and the California Energy Commission.
- Presented at this year's ETCC summit in San Francisco on evaporative pre-coolers and integrated solutions for future market needs.
- Attended the E-Source Leadership Council Meeting.
- Sarah Outcault, WCEC's Behavioral Scientist, gave a presentation and poster session at this year's BECC Conference.
- Spoke at the UC Davis Winery Sustainability workshop, which represents the majority of wineries in California, to expand our scope of solutions/research to include industrial scale energy efficiency solutions.
- WCEC hosted a variety of tours for high school and college level students and science educators to promote energy efficiency education—an important part of WCEC's mission.
- Chaired the 2015 International Conference on Nano, Micro, and Minichannels that was co-organized with InterPACK in San Francisco, CA.

Developing a Phase Change Research Laboratory

Phase change processes such as boiling and condensation of fluids play a critical role in HVAC, refrigeration, power generation, and thermal management (electronics, avionics, spacecraft cooling). WCEC's new Associate Director, Dr.

Vinod Naranayan, is developing a Phase Change Research Laboratory that will help characterize the physical mechanisms affecting phase change processes, enhance these mechanisms, and result in compact equipment design for the above applications.

"Heat and mass transfer processes work most efficiently at smaller scales—the human circulatory system is a case in point. To enable further efficiency in energy technologies, we are leveraging new fabrication methods such as additive manufacturing to create novel, micro-scale heat exchangers." — *Vinod Narayanan, Associate Director WCEC*

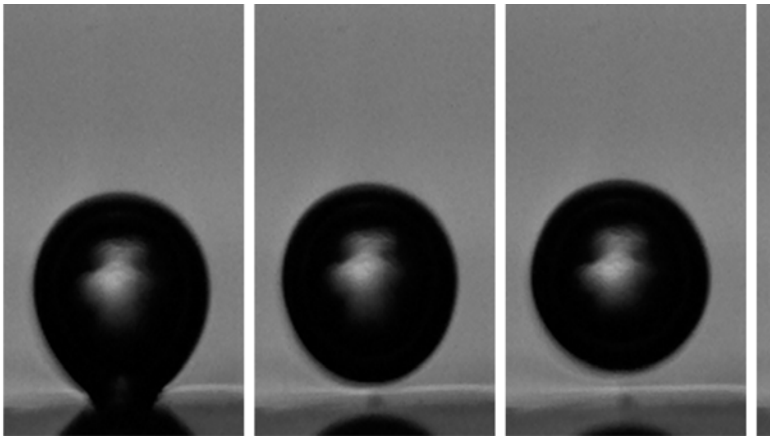
In conjunction with the research being conducted at the Phase Change Research Laboratory, WCEC is designing and fabricating microchannel heat exchangers through a project funded by DOE. Micromachining and additive manufacturing methods are being applied to create novel, compact heat exchangers for high temperature, high pressure applications. This work aims to create more efficient heat exchanger designs and a better understanding of heat exchange surface behavior.

Installing a Solar Thermal Test Facility

With support from the Department of Biological and Agricultural Engineering, a 7-meter parabolic solar concentrator is being installed near West Village on the grounds of the Western Center for Agricultural Equipment. The two-axis tracking dish will be capable of generating up to 25 kW of thermal energy at its receiver at temperatures of up to 800°C and concentrations of solar energy up to 1,000 suns. This facility will provide industry stakeholders with a test bed for solar cooling, solar fuels, and concentrated photovoltaic research.

Investigating Whether Reducing Global Warming Potential and Increasing Efficiency is Possible With Just a Refrigerant Replacement

WCEC performed controlled laboratory testing of a packaged roof top heat pump before and after replacement with a new refrigerant blend (DR-55) identified by Ingersoll Rand from within Chemours' refrigerant portfolio. The refrigerant



High speed video of vapor bubble rising in a pool of liquid from an isolated microheater. Recorded Frame Rate: 10,000 fps.

reduces the Global Warming Potential (GWP) to levels similar to R-32, but with lower flammability. The results show that the equipment operating with DR-55 refrigerant achieved similar capacity to the equipment operating with R-410A, but used less total power in each test performed. The combination of providing comparable cooling capacity, while using less power, is what results in the higher efficiency observed for the unit operating with DR-55. DR-55 showed a 5% improvement in the equipment coefficient of performance at the AHRI rated condition (95°F) and 4% improvement in coefficient of performance on average across all tested conditions. WCEC has also generated unanticipated interest from manufacturers for using Center facilities as a source of third party testing.

Demonstrating the Use of Evaporative Cooling

WCEC has continued its advocacy for climate appropriate cooling, demonstrating the use of evaporative cooling as a solution for both energy use and peak demand reduction in dry climates. Climate appropriate cooling successes include the rooftop unit retrofit project and an increased adoption rate of evaporative solutions through the Western Cooling Challenge. WCEC recently finished laboratory testing on two designs of sub wet-bulb evaporative chillers (SWEC). One design, the Nexajoule technology, was featured in a demonstration home as part of the Solar Decathlon competition in Irvine, CA. A field demonstration of the second technology, an international partnership with Tsinghua University in China, is being planned.

Indirect Evaporative Dedicated Outdoor Air Unit field testing at Whole Foods in San Ramon, CA.

Evaluating Whether Evaporative Cooling Make Sense in California

The potential for significant energy savings and peak demand savings through evaporative cooling technologies is well documented. If indirect evaporative cooling was used on all commercial buildings in California, the annual electricity savings would be roughly 4,000 GWh, which is equivalent to taking 600,000 automobiles off the road. The total annual water use to supply all this evaporative cooling would be 0.11 million acre feet, equivalent to 3% of all urban landscape water-use. While the consumption is minimal, it still represents a concern that is made more significant due to California's drought.

The Center is working on a paper to characterize how evaporative cooling fits into the water-energy nexus, taking into account the embedded energy/water impacts of both energy generation and distribution, and energy impacts of fresh water generation through desalination. One important factor, not often discussed with water conservation topics, is the embedded water-use for most municipal energy creation. Evaporative cooling's energy savings partially offsets this water-use for source energy generation, such as cooling of natural gas-fired power plants. Furthermore, there are other methods to fuel evaporative cooling, such as using captured rainwater that is generally non-potable. Another way we could fuel the water needs for evaporative cooling is through desalination of ocean water. Desalination offers an almost unlimited water resource, but the cost is its energy consumption, which is significant: 1 kWh is required to produce 70-100 gallons of water using desalination. Though that is non-trivial, evaporative cooling only consumes 2-10 gallons per kWh saved. This means that the 1 kWh used to desalinate ocean water could be used to save 7-50 kWh in cooling energy consumption. Additionally, desalination can operate at off-peak hours at night, while evaporative cooling can reduce peak demand during the day, offering a load balancing resource for utilities.

> "If indirect evaporative cooling was used on all commercial buildings in California, the annual electricity savings would be roughly 4,000 GWh, which is equivalent to taking 600,000 automobiles off the road." — *Jonathan Woolley, WCEC Associate Engineer*

Developing Upcoming Research Projects

- **Codes & Lessons Training Courses for the California Energy Commission:** WCEC will create HVAC-related courses and video training modules to support plans examiners and building inspectors with regard to 2016 Title 24 building code requirements.

Jose Garcia, WCEC Assistant Engineer, sealing ductwork for WCEC's laboratory environment chamber.

- **Laboratory Testing a Gas Engine Heat Pump (GEHP):** WCEC is characterizing the performance of a GEHP in the laboratory. GEHPs have the potential to shift peak electricity demand and diminish line-losses by using natural gas instead of electricity to provide building heating and cooling.
- **Total Efficiency of Residential Air Conditioning System with Duct Losses:** Emerging residential split air conditioning systems are being designed with variable speed blowers and compressors. Unfortunately, the location of the ductwork in homes resides mostly in unconditioned attics. When a variable speed system operates at part load, the flow rate of the air through the duct system will be reduced and the conditioned air will spend more time in these ducts that are subject to large thermal loads, diminishing a portion of the energy saved from lower fan speeds. WCEC will create a laboratory test to characterize the overall efficiency of the combined variable capacity air conditioning and duct system.

Update: Center for Water-Energy Efficiency

The Center for Water-Energy Efficiency (CWEE) continues its commitment to identifying, developing, and testing innovative technologies and practices for aggressive improvements in water-energy efficiency; designing policies and outreach activities that facilitate market access and penetration of innovative water-energy conservation strategies and technologies; and serving as a collaborative hub for universities, industrial partners, and government agencies to advance water-energy research, education, technology development, and policy assessment. As the Center embarks on its fifth year, there are notable accomplishments to share.

Energy and Water Data Analytics

CWEE's early work, funded by PG&E, to map the energy intensity by pressure zone within the East Bay Municipal Water District has been replicated at additional water utilities. This research shows that energy intensity typically varies ten fold across a utility's service territory. In 2015, CWEE worked on the following projects to enhance our understanding of energy intensity of urban water systems:

- With funding from San Diego Gas & Electric (SDG&E), the Center expanded its energy intensity analysis. The Center evaluated both the energy intensity of water within a retail water utility (in this case, Otay Water District) and also included the upstream embedded energy of the water from the wholesaler, San Diego County Water Authority.
- Also in 2015, the Center launched a one-year project with Los Angeles Department of Water and Power (LADWP) to calculate the energy intensity of water in the largest public utility in the country, and a highly complex system. The LADWP work will include, for the first time at a large scale, the energy intensity of the sanitation/wastewater treatment of water in the overall energy intensity calculations.

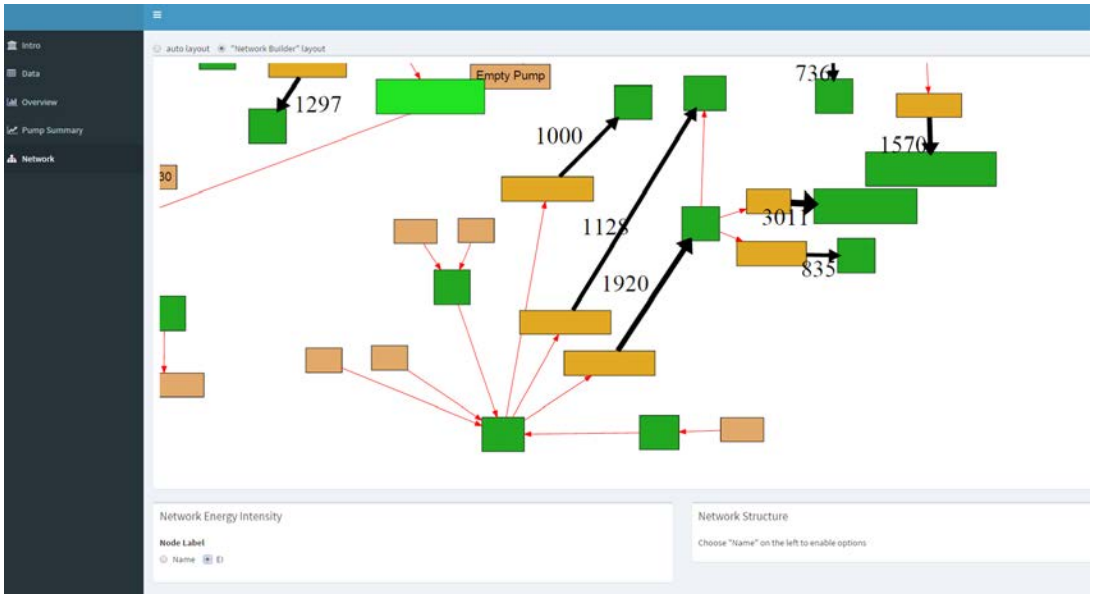
"CWEE is now partnering on research projects with California water utilities that provide service to 7.8 million customers or 20% of the state population. We are excited by the potential to work with so many outstanding utilities and potentially impact so many Californians with our mission to enable the joint conservation of water and energy resources." — *Frank Loge, Director, Center for Water-Energy Efficiency*

- Thanks to support from the George and Cynthia Mitchell Foundation, CWEE completed one year of research with Austin Water, providing energy intensity analysis of their system. With a second year of funding in 2016, the Center will embark on research to use the existing data to explore the impacts of alternate water system operations on electricity consumption load curves, and leverage customer consumption and water conservation program data to determine the most effective approaches to jointly maximize water and energy savings. Using these additional data sets, the Center will model a proposed water conservation program (or portfolio of programs) and analyze the estimated water and energy savings of the program, the projected program costs required to achieve these savings, and a methodology to measure and verify the savings of past and future programs.
- In 2016, the Center will begin projects with Cal American Water in Sacramento to develop pump efficiency and pressure optimization recommendations in their Sacramento water operations. With additional funding from SMUD, CWEE will calculate energy intensity of Cal American's water system and evaluate the water savings, energy efficiency savings, and associated greenhouse gas emissions savings from various water conservation strategies implemented within Cal American's overlapping service territory with SMUD. The Center is also developing projects with the City of Anaheim, funded by the Metropolitan Water District of Southern California, and a project with Long Beach Water.

Technology Advancements

Necessitated by the quantity of highly granular energy, water, asset, operational, and customer data that is required to conduct the Center's research, CWEE has spent much of this year developing technology solutions that allow for rapid ingestion of data and a scalable data platform. First, CWEE built a computer graphic interface that allows users to drag and drop icons to build an accurate asset framework, showing the relationship and connections between the elements of a water system. Additionally, this tool allows users to drag and drop the associated data files, whatever their format (raw

SCADA data, excel worksheets, etc.) on to the icon to populate the asset with the necessary data needed to complete our research and analysis. This tool is named the CB Network Builder.



Example of CB Network Builder showing assets in a water system, corresponding energy inputs and cumulative energy at each node in the system.

Recognizing the need to manage huge quantities of data, provide the appropriate security and privacy for critical infrastructure information and personally identifiable customer information, develop analytics, apply the most advanced machine learning capabilities, and develop a platform that will rapidly scale, the Center partnered with Microsoft to build a cloud based data platform. This platform will conform to the most rigorous safety, security, and privacy standards; and will be governed by the terms of a "trust framework." In 2016, the Center will launch pilot projects with eight to ten California water utilities to upload their data into the platform, perform analytics, and safely share data both within their own operational units and, if the utility wants, to outside parties, such as other utilities, university researchers, or start up companies.

With funding from the S.D. Bechtel, Jr. Foundation, CWEE will convene a data security and privacy workshop in early 2016 with water and energy utilities to define best practices, identify the value proposition for a cloud based data platform, and identify barriers to overcome in order to enable utility participation in such a platform.

Water Rate Structure Updates

In the past year, CWEE has continued its research and development of Consumption-Based Fixed Rates (CBFR), a water rate structure that enables water conservation without threatening the income stability of water utilities. CWEE's work on developing the CBFR method, and the related implementation challenges, was published in the *Journal of American Water Works Association* in February 2015. The papers discuss the innovative design of the rate structure, the adoption challenges of implementing CBFR in the City of Davis, and the equity implications of CBFR in relation to more conventional water rate structures.

CWEE's rate equity study has the potential to be particularly influential on future rate design and adoption. A utility's water rate structure includes an inherent amount of water that must be used before the fixed part of the rate is effectively paid for and each additional unit of water used only costs the variable rate. This "consumption to fairness" value varies based on the rate structure's proportion of fixed and variable components, and this indicator can be related to household income to estimate the equitability of a range of rate structures. Using the City of Davis as a case example, CWEE shows a negative correlation between household income and the number of people paying unfair rates (i.e. using less water than the "consumption to fairness") under conventional water rate structures. Importantly, this effect can be diminished for rate structures with large volumetrically-based proportions, such as CBFR. CWEE believes that this approach will evolve into an important tool for utilities to ensure rate equity when

considering the implementation of new water rates in their territory. A publication on the rate equity research is under development and is expected in 2016.

Behavior-Based Conservation

In late 2015, the California Department of Water Resources awarded CWEE a grant to implement behavior based conservation strategies in three economically disadvantaged communities in California. This project will extend research into the effects of different messaging strategies on the adoption of water and energy conservation goals. Under the grant, the Center will launch projects with Modesto, Ontario, and Riverside water customers.

The Center continues groundbreaking work in the City of Burbank, funded by So Cal Gas to assess behavior-based water conservation through technology deployment and data analysis, using a randomized control trial and various messaging to selected groups of residents. A control group receives no messaging. The first treatment group receives standard water conservation messaging. The second treatment group receives messaging specifically tailored to reduce hot water use. The third treatment group is invited to participate in a water- and energy-saving competition with the greatest savers receiving a prize for their efforts. Burbank represents a city that has high-resolution, interval data for all household utilities, including water, gas, and electricity. Leveraging this "big data" on the residential side will allow CWEE to measure and verify the water, hot water, and resultant energy savings from the WaterSmart intervention. By running this full-scale experiment, CWEE will determine the effectiveness of this approach, which has the potential to generate significant water–energy savings with very little capital investment.

Agriculture

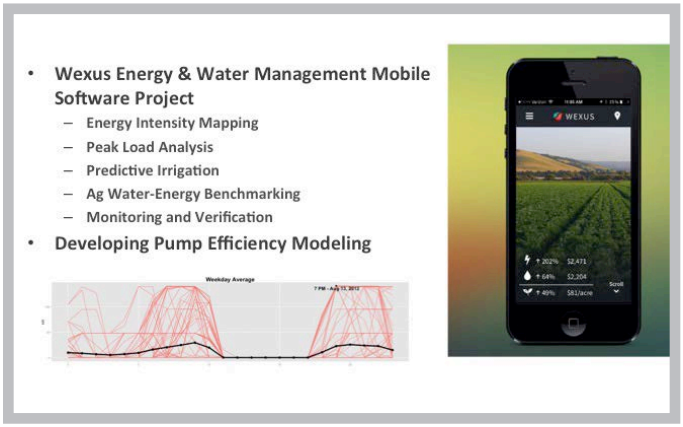
Also in 2015, CWEE began work with an agricultural water-energy start up company, Wexus Technologies, to study the integration of water and energy data via a smart phone app to optimize energy conservation and pumping times by agricultural growers. This two-year project, funded by the California Energy Commission, will enable the Center to engage directly with growers in California to begin to apply the Center's advanced water-energy data integration and analytics to enable joint conservation of resources.

Demonstration app that allows residential customers to explore their historic use and impact of implementing various water conservation strategies. The app then calculates the resulting water savings and greenhouse gas emission savings of the conservation strategies selected.

With CWEE Associate Director, Ned Spang's appointment to an Assistant Professor position in the Department of Food Science and Technology, food processing and agriculture water/energy projects will become an increasingly large part of the Center's research portfolio.

Drought Response and Outreach

The historic California drought and the Governor's mandated urban water reductions, brought new opportunities to highlight the Center's work with elected officials, and legislative and policy leaders across the state. Faculty leaders Frank Loge and Ned Spang attended numerous workshops and summits, briefed state officials and business leaders, and worked with water utilities on strategies to enhance decision making using the Center's integrated, enterprise-wide data driven approach. The many new connections, large network of potential collaborators, and high visibility for CWEE's work, provide an exciting platform for continued growth in the coming year.



CWEE is partnering with Wexus to help agricultural growers in California use mobile devices to visualize water and energy data and enable joint management and conservation of framing operations.

Update: Plug-In Hybrid & Electric Vehicle Research Center

The Plug-In Hybrid & Electric Vehicle (PH&EV) Research Center collaborates closely with California utilities, the Electric Power Research Institute, automakers, and other research institutions on research aimed at developing a sustainable market for plug-in vehicles. The Center began with three initial research projects, and with the development of a PH&EV Research Roadmap, identified high-priority research areas for future research, including consumer perspectives and vehicle use, charging infrastructure, fleet market development, battery studies, and the impact of human-machine interfaces on behavior. Moving forward, our research is focused on measuring, monitoring, and understanding multiple aspects of the quickly evolving market for plug-in vehicles internationally.

The PH&EV Research Center completed the first full year of data collection in a multi-year longitudinal research program called "Rollout and Ramp-up," which is designed to advise stakeholders in the Plug-in Electric Vehicle (PEV) market. This project is supported by a group of stakeholders, with major funding from the California Energy Commission, U.S. DOE, and California Air Resources Board (CARB), with additional support from PG&E, SMUD, SDG&E, BMW, Subaru, Alliance of Automakers, and ChargePoint. This work was reported to partners in the *Deep Dive* workshop held at Asilomar on Aug. 17, 2015. This program has four main components.

1) Awareness, Knowledge, Experience, and Attitudes Towards Zero Emission Vehicles (ZEVs) Among California and American Car Buyers (not PEV buyers)

Given the importance of expanding ZEV markets, the Center studies consumer concerns about ZEVs. Dr. Ken Kurani led annual survey and interview work in California and 12 other U.S. states, which resulted in 10,000 completed surveys in the past the 12 months.

Comparing new car buyers in West Coast and East Coast states, Center researchers found that car buyers in Western states are presently more receptive to all types of ZEVs (PHEVs, EVs, and FCEVs). Among those in both regions who are not receptive, motivations against ZEVs are broadly similar. Figures 1a and 1b show three clusters of respondents who share similar concerns. The scale is the mean score of each concern within each cluster. Across regions the clusters are identified by similar highly scored concerns.

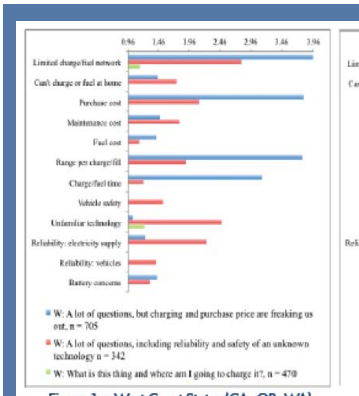


Figure 1a: West Coast States (CA, OR, WA)

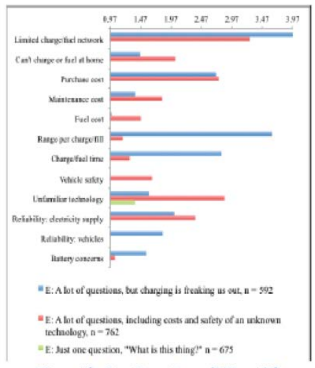


Figure 1b: East Coast States (MD to ME)

2) Development of the New and Used Plug-in Electric Vehicle (PEV) Market in California and the U.S.

Dr. Gil Tal led annual surveys and interviews with California and U.S. PEV buyers. Over 10,000 California and U.S. PEV buyers have been surveyed in the past 12 months. Center researchers analyzed the response of PEV owners to a set of stated preference questions about whether they would have purchased a PEV, an ICE, or any new car if the federal tax credit had been available at the time of their vehicle purchase. Center researchers found that the federal tax credit triggers about half of the Nissan Leaf sales, far more than the sales of the Tesla and short-range plug-in hybrids.

The full impact of the federal tax credit is analyzed in a forthcoming *Transportation Research Board* paper, while the impact of non-momentary incentives such as HOV access was presented in a 2015 TRB paper and will be fully analyzed in a new forthcoming paper.

3) PEV Travel and Charging Behavior (eVMT)

Funded by both CARB and the California Energy Commission, Dr. Mike Nicholas led a project to improve our understanding of PEV travel and charging behavior. This project is fully underway, with the first 72 household loggers installed as of early September 2015. The Center will add Tesla Model S and BMW i3 models to our data collection efforts in the next few months, as the additional funding contract is finalized and loggers are procured.

Center researchers have analyzed data from the recruitment survey of nearly 5,000 California PEV drivers. Early results show that there is significant variation in the annual mileage traveled by different Battery Electric Vehicles (BEVs) with similar range, and there is a plateau after approximately 120 miles in terms of how many additional annual miles are achieved through greater BEV range. Further research will study the impacts of factors such as vehicle switching, infrastructure access, number of cars and drivers, and the cargo/utility of individual vehicles, among other factors.

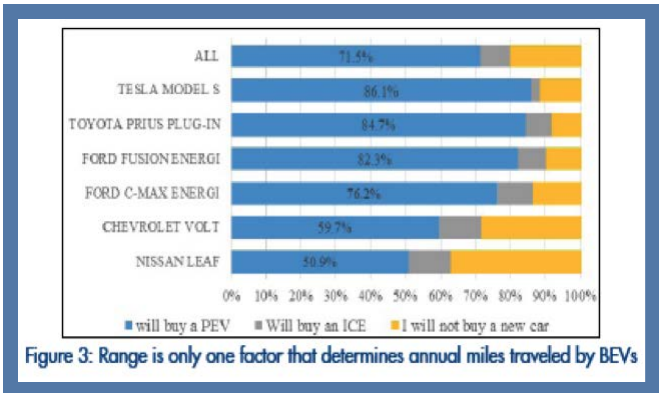


Figure 3: Range is only one factor that determines annual miles traveled by BEVs

4) Development of World PEV Market

Dr. Tom Turrentine is leading an analysis of monthly and annual world PEV market sales, policy, and registration trends. The sales trends will be considered in the context of other market influences, including regional policies, ongoing research and development, increasing availability and reliability of charging infrastructure, more vehicle styles available on the market, and the experiences of early PEV drivers.

Update: Child Family Institute for Innovation and Entreprenuership

The Child Family Institute for Innovation and Entrepreneurship brings together researchers in science and engineering with faculty, MBA students, UC Davis undergraduates, experienced entrepreneurs, investors, and corporate leaders to support technology transfer and commercialization activities. Our programs help researchers and students build the networks, knowledge, and tools to communicate the value of their work, explore commercialization strategies, connect with industry partners, and design research programs that address and align with practical applications. Some notable highlights in 2015 are:

Forming A New Partnership to Expedite Technology Transfer

With a shared goal of speeding the transfer of new technologies from the laboratory to the marketplace, the Institute, Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratories (Sandia) announced a new partnership. The Institute's unique approach to training – focusing on developing a network of support for those within large academic and research institutions – has been an ideal fit for the national labs. Two important innovation projects evolved from this partnership: Lab Corps and the National Labs Entrepreneurship Academy.

- **Lab Corps:** Together with the Livermore, California–based i-GATE Innovation Hub, LLNL and Sandia received a $350,000 grant from the U.S. Department of Energy's, Energy Efficiency and Renewable Energy office to launch a pilot program, known as Lab Corps in January 2015. Lab Corps is intended to help national lab scientists and engineers become better entrepreneurs and to move innovative technologies into the marketplace. Through Lab Corps, researchers attended a series of seminars with the Institute and i-GATE to prepare to pitch their projects in March before a team of judges. The winning teams each received $75,000 to develop commercialization plans for their technologies. LLNL team *Optimization of Building Efficiency* aims to improve energy efficiency in commercial buildings through better control technology. Sandia team *Twistact's* technology enables novel wind turbine designs that eliminate exotic rare-earth materials and high-maintenance components. These teams will also complete additional national Lab Corps training, and have access to a suite of commercialization resources.

> "The national labs have recognized that we have a unique approach to training in that we focus on developing a network of support for those within large academic and research institutions." — *Andrew Hargadon, founder and faculty director of the UC Davis Child Family Institute for Innovation and Entrepreneurship*

- **National Labs Entrepreneurship Academy:** In June 2015, nearly 50 researchers from LLNL and Sandia attended the first-ever National Labs Entrepreneurship Academy (NLEA) at the San Ramon campus of the UC Davis Graduate School of Management. LLNL's Industrial Partnerships Office organized the event in collaboration with Institute staff. The three-day academy is designed to help drive innovation at the labs by teaching Lab scientists and engineers the entrepreneurial skills that will help them in the innovation process, whether they are working with industry or government sponsors, or, if they choose, becoming part of a startup based on Lab technology. The inaugural NLEA attracted 36 LLNL and 13 Sandia researchers and scientists. Based on the positive feedback and lab enthusiasm for the program, a second NLEA was held in November 2015 with 21 LLNL and 22 Sandia participants. There are plans underway to host another academy in 2016. During these academies, the Institute has been able to bring together local and regional resources, mentors, and speakers to actively

cultivate the culture of innovation centered around national lab technology in the Tri-Valley area.

Hosting the Big Bang! Business Competition

Hosted by the Institute, the Big Bang! is the largest annual business competition in the Sacramento region. The Big Bang! provides a year-round forum for new and early-stage startups to collaborate, develop, and test business ideas. Resources include team creation, education, mentorship, networking, and financing. Last year, the competition awarded nearly $40,000 in prize money. This year's winners will take home more than $60,000.

The Institute recently kicked off the 2015-2016 Big Bang! season with a record turnout for our opening event on October 27. The competition is evolving to emphasize innovations in clean energy, food and agriculture, biomedical, and technology. Besides the First, Second, and People's Choice prizes, the 2015-2016 competition will award a new $10,000 Syngas Challenge Award, the Gary Simon CleanTech Award, a UC Davis Biomedical Innovation Award, a CITRIS award for development of apps in the interest of society, an award sponsored by Davis Roots, and more.

Advancing SATIC and Agricultural Innovation

In addition to the national labs partnership, the Institute continued to move forward with its Sustainable AgTech Innovation Center (SATIC), funded by a $1 million grant from the US Department of Commerce's Economic Development Administration's 2012 i6 Challenge: Sacramento Region Clean AgTech Innovation Center Development Project. SATIC supports the commercialization of clean and sustainable agricultural technologies by focusing on identifying and accelerating new ventures promoting sustainability in the agricultural field —including new agricultural practices, water and energy efficiency in production and food processing, advances in nutrition, food quality and safety, and new food products. The key programs in 2014-15 included the Village Capital Venture Forum and the Agricultural Innovation Entrepreneurship Academy.

15th annual UC Davis Big Bang! Business Competition Kickoff on October 27, 2015.

- The Village Capital Venture Forum was a two-day event in February 2015, co-sponsored by Village Capital out of Louisville, Kentucky. This organization fosters early stage agricultural startups by touring them across the United States to pitch and receive feedback on their ventures.

- The Ag Innovation Entrepreneurship Academy in April 2015, was designed for researchers and early-stage start-ups working in agriculture and food to support commercialization of agriculture and food systems technologies. The academy combines focused lectures, practical exercises, networking sessions, and hands-on experiences in an innovative format to help participants explore how their research can make a broader impact in industry, the marketplace, and the world. With the help of over 60 speakers and mentors, nearly 50 academy participants learned to identify market needs and opportunities, develop a network of experts to support their venture, and create agriculture 'food chain' clusters of innovation.

Update: Policy Institute for Energy, Environment and the Economy

Created in 2012, the UC Davis Policy Institute for Energy, Environment and the Economy leverages university expertise and engages directly with decision-makers to deliver credible, relevant, and timely information and analysis to inform better energy and environmental policy.

The Policy Institute responds to the challenge faced by governments at every level to promote a healthy, growing economy, while simultaneously improving environmental quality, increasing efficiency, diversifying the energy supply, creating greater resiliency to energy disruptions, and responding to climate change. The Institute accomplishes its mission through various activities and initiatives. A few 2015 highlights of the Policy Institute's work are identified below.

New Executive Director

In August, federal agency climate leader and UC Davis alumnus Dr. Katharine (Kit) Batten became the new executive director of the UC Davis Policy Institute for Energy, Environment and the Economy. Dr. Batten is working to grow the Policy Institute's existing significant programs in zero-emission vehicles, low carbon fuels, energy efficiency, and climate change adaptation, as well as to initiate new work in clean power, climate resilience, and the agriculture-energy-water nexus. New initiatives include an Op-Ed series published in Capitol Weekly, targeting Sacramento policy makers, on the need to continue pushing drought-related policies in the face of the El Nino (e.g., groundwater, fire prevention, and ecosystem water need policies). Additionally, Dr. Batten and the Policy Institute are working closely with the Provost's Office on leading a campus-wide conference on the UN Sustainable Development Goals to be hosted on campus in November 2016.

> "My passion is to ensure that the best available science and research influences public policy, and it has driven my career. I am honored to return to UC Davis after a decade of policy making in Washington, DC to connect the cutting-edge research conducted on campus to state, federal and international policy." —*Kit Batten, Executive Director of the UC Davis Policy Institute for Energy, Environment and the Economy.*

Kit Batten, the Policy Institute's new Executive Director.

New Senior Policy Fellow on Energy and Transportation Policy

Former California Assemblymember Nancy Skinner joined UC Davis as Senior Policy Fellow for the UC Davis energy and transportation programs, including the Energy Efficiency Center, Institute of Transportation Studies, and the Policy Institute for Energy, Environment and the Economy. Skinner's expertise is helping ensure that energy and transportation research better informs governmental actions. For example, as a result of Skinner's work and that of EEC staff, UC Davis energy and transportation efforts were incorporated into the Energy Commission's final report on AB 758 implementation, "The Comprehensive Energy Efficiency Program for Existing Buildings," the University of California's Climate Summit event and report "Bending the Curve: Ten Scalable Solutions for Carbon Neutrality and Climate Stability," and the State Water Resources Board grant guidelines. A few key highlights from Skinner's work in 2015 are:

- Appointed by President Janet Napolitano to the Global Climate Leadership Council (GCLC), the task force coordinating UC's systemwide Carbon Neutrality Initiative. This Initiative aims to emit net zero greenhouse gases from buildings and vehicle fleets by 2025. Skinner participated in the GCLC task force meetings and facilitated partnerships between EEC's Industry Council and UC's systemwide efforts.
- Facilitated Commissioner-level communication between EEC researchers and staff and the California Energy Commission to increase Commissioners' knowledge of EEC activities and resources.

- Coordinated EEC review and comments on the draft implementation plan for AB 758—the legislation aimed at increasing energy efficiency of commercial and residential buildings built pre-Title 24.
- Served as guest instructor and advisor, and assisted with syllabus development, for a UC Davis graduate seminar, "Translating Research to Policy."
- Secured speakers for, and served as facilitator for the Government Leaders panel, at the UC systemwide Climate Summit held in October 2015 at UC San Diego, and advised on content and author submissions for the "Bending the Curve" report.
- Spoke at a number of conferences and seminars, including the Alliance for Clean Technology Solutions, United Nations Association Climate Symposium, and the California Association of Environmental Professionals meeting.

"I had a great year as Senior Policy Fellow with the Energy Efficiency Center. The Energy, Transportation, and Policy Institute research cluster at West Village is a vibrant community engaged in cutting edge and innovative research, with great potential for interfacing with and influencing the public and private sector."
— Nancy Skinner, UC Davis Senior Policy Fellow on Energy and Transportation Policy

Industry Advisory Council Provides Critical Connections

An informal Industry Advisory Council was established to support our Senior Policy Fellowship program, to give active parties in the private sector an opportunity to provide valuable practical feedback, and to help bring relevant research to the attention of the marketplace. Industry Advisors to the Senior Policy Fellow in 2015 were:

- Bruce Dickinson, Director, SunPower Corporation
- Lance Holman, President & CEO, Holman Capital Corporation
- Tom Jackson, Corporate Vice President, Climatec
- Mike Petouhoff, Global Energy Manager, Apple
- Tom Riley, Vice President, EnerNOC

Former California Assemblymember Nancy Skinner and California State Senator Fran Pavley at the University of California's Climate Summit. Photo: Erik Jepsen

Future Opportunities

Governor Brown has signed into law SB 350, mandating a 50% increase in the energy efficiency improvements projected for California buildings with the Energy Commission as lead agency. This law provides the EEC new opportunities to proactively interact with the Commission to develop partnerships and innovative strategies for achieving SB 350 goals.

Carbon neutrality is also a critical issue and goal for many organizations and businesses, including the University of California. The EEC has unique expertise that could help advance this issue and assist organizations and businesses in meeting their carbon neutrality goals.

Update: Program for International Energy Technologies and D-Lab

Founded in 2009, the UC Davis Program for International Energy Technologies (PIET) and D-Lab seek to accelerate the development and commercialization of low-cost, clean, and efficient energy technologies worldwide.

In keeping with its international focus, PIET and D-Lab are engaging more students than ever on real-world, innovative, and hands-on energy projects on campus and abroad. With a focus on market-based energy solutions in both developed and developing countries, multidisciplinary faculty and student teams work with clients to understand their specific technical, social, environmental, and economic issues.

Climate Neutrality Research and Education Initiative

In October 2015, Dr. Kurt Kornbluth received the University of California Climate Champion Award. In addition to building a technical-economic model for climate neutrality to guide the UC Davis Climate Action plan, the PIET team will work with other faculty to create new project-based curriculum focusing on development of an investment portfolio of UC-Davis based CO2 reduction projects.

As the newly-awarded Climate Champion, Kurt Kornbluth and the PIET assist the UC Davis Office of Environmental Stewardship and Sustainability in building an economically viable roadmap to Zero Net Energy and Climate Neutrality for the UC Davis campus.

Zero Net Energy Initiative

Supported by the UC Davis Energy Conservation office, the Zero Net Energy Initiative, continues to provide outreach and education, as well as save energy on the UC Davis campus. During 2015, student teams worked on a variety of projects, including a feasibility study for UNITRANS on the implementation of electric buses. This study is ongoing with an effort to identify funding sources to pilot two buses in 2016.

International Development Innovation Network

As a member of the USAID-funded International Development Innovation Network, D-Lab works with a consortium of universities to develop energy technology targeted at poverty alleviation. In 2015, PIET graduate students coordinated with partners in Cali, Colombia to organize a two-week design summit focusing on projects that reduce waste in the city. In the summer of 2016, the UC Davis D-Lab team will take a lead role in "IDDS Amazon" a permaculture-focused Design Summit in Brazil.

US/Denmark Renewable Energy Summer Course

The US/Denmark Summer Renewable Energy Course, supported by a National Science Foundation PIRE grant, brings US and Danish students and faculty together to study renewable energy issues in California and Denmark. This course is organized in collaboration with UC Santa Cruz (UCSC), Aalborg University, and Danish Technical University. Highlights for the 2015 edition, held in Denmark, hosted by

UCSC and UC Davis, included a study to determine the cost of substituting biomass resources for the current fossil-based electricity generation on the UC Davis campus. A summer 2016 course, to be hosted at UC Davis and UCSC, is currently being planned.

Efficiency in the Wine, Food, and Beverage Industry

As the nation's largest food processing state, California contains many opportunities for recovering both waste heat and water in food processing facilities. To understand where recovery efforts can have the greatest benefit to resource efficiency, current water and energy use in food processing must be understood and quantified.

The UC Davis Sustainable Winery

The UC Davis Robert Mondavi Institute for Wine and Food Science (RMI) houses a state-of-the-art research and teaching complex made up of three academic buildings, the Teaching and Research Winery, the Sensory Building, and the Jess S. Jackson Sustainable Winery Building.

The UC Davis Teaching and Research Winery was designed to be the world's first self-sustainable winery, meeting all of its energy and water needs from on-site capture and sequestering all carbon dioxide produced during fermentation. The Winery is the first LEED Platinum building on the UC Davis campus, and the first of its kind in the world. In an era in which "net zero" is the latest mantra of sustainable design, this building is water and energy positive—it actually makes more electricity and captures more rainwater than it uses—thanks to the solar arrays on the roof and its rainwater storage tanks. The Winery was initiated by a gift from Robert Mondavi, and lifted to a Platinum level building by a group of donors led by Jess Jackson, Barbara Banke, and Jerry Lohr.

The Winery will be:

- The most water efficient winery ever built, reusing its processed water at least five times.
- The most chemistry-efficient winery ever built, reusing cleaning chemicals at least five times and exclusively employing green cleaning chemistries.
- The most energy-efficient winery, using on-site solar water heating and cooling systems for fermentation temperature control.
- The first winery to be fully solar powered at peak load on a kilowatt basis, as well as being energy positive on a total kilowatt-hour basis.

Next door to the Teaching and Research Winery, the recently completed Jess S. Jackson Sustainable Winery Building will house the technologies necessary to make the winery fully sustainable. Ten modular spaces will accommodate advanced systems that will: generate and store energy, recover and filter water and cleaning solutions, produce the hot and cold water, and make hydrogen and deliver it to a direct hydrogen fuel cell. Two remaining spaces are available for future research projects related to water efficiency, energy capture, production or storage, and carbon sequestration or by-product recovery from grape or wine waste streams.

Advanced fermentation tanks in the UC Davis Teaching and Research Winery.

The systems for the Jackson Building will be installed on loan agreements, rather than purchased or gifted. This will encourage replacement and renewal as technologies change and systems improve in performance. Systems will be advanced commercial or near-commercial, and the operational performance of each will be measured and displayed on a Winery web-page. The Winery's intention is to publicly present the first real-time, energy/water/carbon footprint and performance information of an operating Winery and LEED Platinum building.

The Jess S. Jackson Sustainable Winery Building was recently named as the best "Overall Sustainable Design" by the 2014 Energy Efficiency and Sustainability Best Practices Competition for all university buildings in California, within the UC and the Cal-State system.

Jackson Building Systems include:

- Water: The water system will be supplied by rainwater, harvested from the roofs of the RMI buildings, that is filtered using reverse osmosis and stored until required for the harvest. Rainwater filtration will take place over several months so that facility power needs are minimized and energy use is distributed over a long period, without the demand peaks, which result in surcharges and cause grid disruption. The rainwater will feed an advanced clean-in-place system, which adds green cleaning chemistries, washes the tanks, and captures and filters the spent solutions for re-use rather than releasing them as wastewater after one use, as is usual practice. The Winery's goal is to use one fifth of the normal water and chemistry of the water typically used by a commercial winery. The little wastewater remaining can be used as irrigation water and the organic wastes will be sent to the campus biodigester, which generates methane for heating.

  Hot and cold water required for fermentation temperature control will be solar generated. Water will be heated by a passive solar thermal system to a target temperature of 60°C (140°F). Water will be chilled by a solar-powered ice-maker, which accumulates ice during the day so that water can be chilled to a temperature of 5°C (40°F) when cold water is needed.

- Electricity: High efficiency solar panels will generate electricity during the day. This electricity will power the Jackson building systems and will charge second-life lithium ion batteries recycled after reaching the end of their useful life in electric vehicles. A fuel cell operating on hydrogen will provide a secondary source of electricity. The on-site production of hydrogen by future solar-based electrolysis systems is the preferred source of fuel.

- Carbon Dioxide: Carbon dioxide produced during fermentations will be routed through a series of calcium hydroxide absorption columns where the carbon dioxide will be dissolved and precipitate as calcium carbonate. The calcium carbonate (chalk) produced each harvest will be sold to the biofuels industry. This sequestration system will be a future research project, although the Winery and its fermentors have been designed so as to capture all carbon dioxide released.

The Jess S. Jackson Sustainable Winery Building

Once fully operational, researchers will evaluate the Winery systems performances and help commercial wineries determine which systems are best employed for their sustainability and business goals.

Elucidating the Tomato Processing Water-Energy Nexus to Improve Resource Efficiency

Tomato processing is a major industry in California with over 90% of the US's processing tomatoes grown in the state. Producing tomato paste, the primary product of tomato processing, can be resource intensive. Conventional processing uses water to transport, sort, wash, and heat tomatoes. All of these processes also require considerable amounts of energy. This inherent relationship between water and energy defines the water-energy nexus (WEN) for tomato processing. To better understand the tomato processing WEN, and identify where more resource efficient technologies and practices could have the greatest impact, the Simmons lab developed a WEN assessment method.

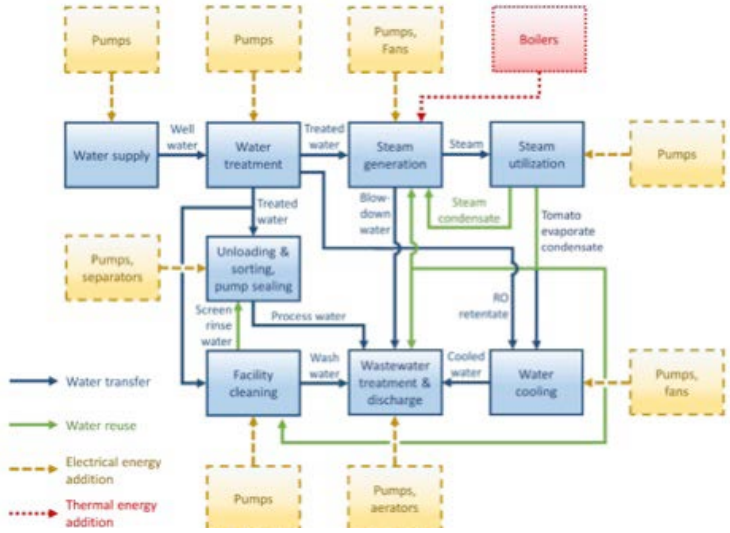
The Lab's WEN assessment methodology considers all the ways that electrical and thermal energy becomes embedded in water during tomato processing. Specifically, it measures the energy use of pumps, fans, boilers, mechanical separators, and aerators that interact directly with water at various points in

the pipeline. Coupled with measurements of water flow through each of these operations, researchers can determine the energy intensity of water at various points during processing. Together, metrics describing total water and energy use throughout the processing pipeline, along with the relative energy intensities of each processing step, can provide targets for where efficiency improvements can be most useful. Moreover, the Lab delivers resource use data at a higher resolution than is typically collected, providing water and energy use data at the level of individual unit operations or equipment. This level of detail provides actionable information for comparing and choosing new resource efficiency measures in tomato processing.

Recently, the Lab demonstrated the WEN assessment at a commercial tomato processing facility. Direct measurements of water and energy use were coupled with heat and mass transfer modeling to quantify use of these resources, at the unit operation level, for the facility's unique configuration. The data indicated the transportation, washing, and sorting flumes were the major water demand for the facility. Large volumes of steam were used for process heating. As a result, the greatest energy input across the processing pipeline was thermal energy derived from natural gas use in boilers. In contrast, the steam system represented a relatively minor water demand due to the indirect heating processes used in tomato processing that allow for steam condensate to be captured and recycled. Energy use in the groundwater pumping, cooling tower, and steam system pumping operations represented major electrical energy demands.

"The best efforts to improve water and energy efficiency in food processing start with developing a deep understanding of how food processors are using these resources today."— *Christopher Simmons, Assistant Professor in the Department of Food Science and Technology*

In addition to enabling more conventional resource efficiency measures, such as repairing pumps, adjusting pump loads, improving insulation, and repairing steam traps, the WEN assessment also allowed for more novel efficiency measures to be analyzed. For example, the WEN data revealed a substantial source of low-grade



The water-energy nexus of industrial tomato paste processing.

waste heat within the water vapor removed from tomato juice during paste formation in the evaporators. In light of this, researchers modeled a novel tomato processing waste heat recovery process where this low-grade waste heat would be used to preheat tomato juice prior to the enzyme thermal inactivation operation that occurs early on in the processing pipeline. We found that the facility could potentially save over $200,000 per year by way of annually conserving over 7,000 kWh in energy from natural gas and electricity if they implemented such a waste heat recovery process.

Such efficiency savings are likely possible across the tomato processing industry. While the Lab's initial work has focused on industrial tomato processing, the WEN assessment method is adaptable and can be translated to many food processing industries. Going forward, the Lab looks to deliver actionable resource use data to inform efficiency improvements across other major food and beverage processing industries, such as wine and dairy.

New Professor to Focus on Water-Energy-Food Resource Systems

Dr. Edward (Ned) Spang was recently appointed an Assistant Professor in the Food Science and Technology Department. In addition to his faculty position, Ned will continue his role as the Associate Director of the Center for Water-Energy

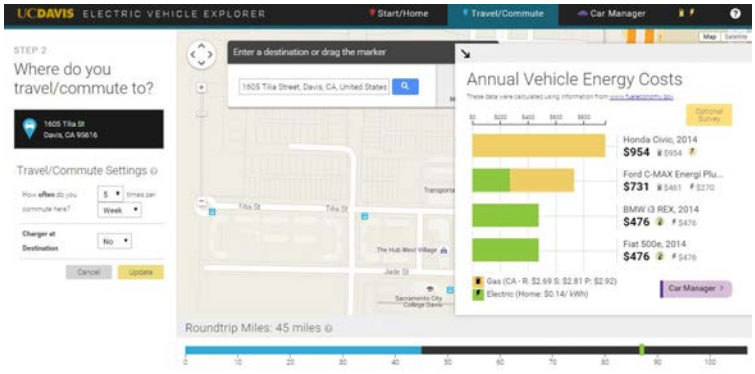
Efficiency. His research focuses on characterizing and optimizing the efficiency of linked water, energy, and food resource systems. Spang is particularly interested in applying methodologies to measure and monitor these systems and their interrelationships in high-resolution and across multiple scales. He also seeks to understand the influence of markets, innovation, and policy on the integrated food-water-energy nexus. Spang's recent publications explore mapping energy flows through water infrastructure, enhancing the conservation signal and stability of water rates, and estimating global water consumption for energy production. He earned his M.A. and Ph.D. from the Fletcher School of Law and Diplomacy, Tufts University.

cEnergi—Optimizing User Interfaces for Energy Awareness

Consumer Energy Interfaces (cEnergi; cenergi.ucdavis.edu) is an interdisciplinary research lab investigating the potential for eco-feedback to promote resilient and sustainable relationships between individuals, communities, and natural resources. Eco-feedback is information about natural resource consumption provided back to the consumer. cEnergi studies eco-feedback from a transdisciplinary perspective, integrating behavior science, design, computer science, and engineering; and aims to be a leader in behavioral theory of eco-feedback and the design of innovative eco-feedback systems.

Web and Mobile Apps

cEnergi creates and evaluates mobile apps and websites that provide feedback to users about the environmental impacts of their behavior. For example, EV Explorer (http://gis.its.ucdavis.edu/evexplorer/) is a website that allows users to compare fuel costs for conventional versus electric vehicles (EVs) based on their own commuting patterns, charging opportunities, vehicle mileage, and local fuel prices. The Lab evaluated EV Explorer through online experimentation, gauging users' perceptions—before and after using the website—of their current fuel costs, potential savings with EVs, attitude toward vehicle charging, and intention to buy or lease an EV in the future. Statistically significant changes in each of these variables validated EV Explorer as an educational and persuasive tool to encourage the adoption of EVs.



cEnergi's electric vehicle explorer website (http://gis.its.ucdavis.edu/evexplorer/).

Flag ceremony at UC Davis West Village.

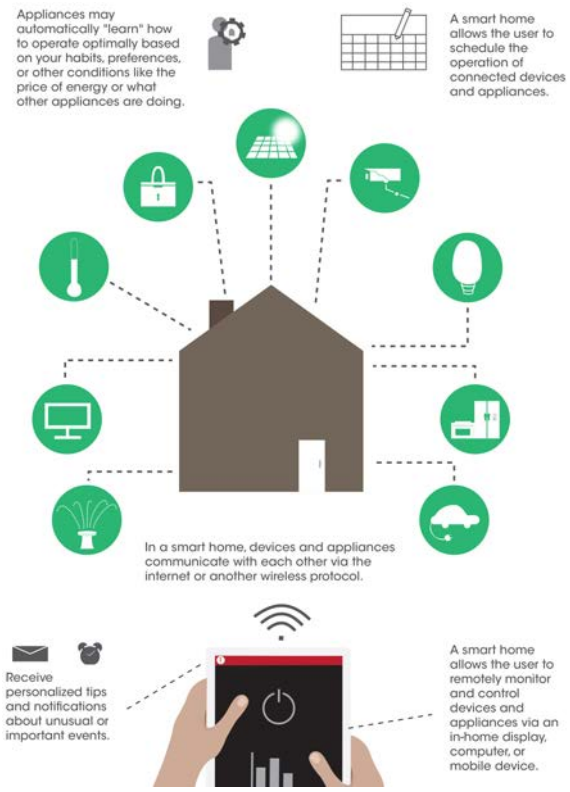
On-Campus Projects

cEnergi also has a number of exciting on-campus projects. The Lab collaborates with the Energy Conservation Office (ECO) at Campus Facilities Management on projects like providing bi-directional thermal feedback for public buildings (therMOOstat.ucdavis.edu) and a campus energy education dashboard (ceed.ucdavis.edu). cEnergi has also created a living laboratory for innovative eco-feedback systems at West Village. For example, the Lab created an energy feedback system for the Plug-in Hybrid & Electric Vehicle Research Center at West Village, consisting of a flag ceremony conducted three times per day, featuring a red or green flag raised outside the office to reflect recent consumption in relation to a ZNE performance goal modeled for the office. A statistically significant reduction in average hourly energy consumption was observed during the feedback intervention. cEnergi is planning to expand the office feedback system by developing digital feedback and including other offices at West Village.

General Research

cEnergi is just beginning a research project with SEE Change Institute for PG&E concerning home energy management (HEM) technology. cEnergi is leading the customer research stream, which includes a survey of PG&E customers to assess perceptions of smart home technology, as well as customer

research at Sears Connected Solutions smart home installation in San Bruno, CA, and Target Open House in downtown San Francisco. HEM technology is the new frontier of residential eco-feedback and we anticipate a high impact for this project, which will develop a roadmap for PG&E's role in the realm of smart home technologies.



Example of Home Energy Management (HEM) technology.

Expanding Educational Programs

As part of its mission to train future leaders in Energy Efficiency, the EEC recognizes the need to develop and deliver energy and energy efficiency coursework, at a variety of academic levels, in order to influence the effectiveness of the workforce of tomorrow. Within UC Davis, we have engaged students across several fronts – through the development of new undergraduate courses, to the engagement of more than 300 students through the experience-based learning project of the U.S. Department of Energy's Solar Decathlon, to the development of an innovative interdisciplinary Energy Graduate Group that is currently under review by the University of California Office of the President.

Energy Efficiency Coursework

In recent years, the EEC and its affiliated faculty have developed and helped to support specialized courses, focused on energy efficiency, to address the industry's most urgent, timely topics. These courses can be taken as electives, or students can pursue a Minor in Energy Efficiency.

Developing a New Model of Graduate Education to Train Future Leaders in Energy

We understand that the energy sector is becoming increasingly complex. Aggressive new policies aimed at combating climate change are putting enormous new stresses on the electric grid and on utilities as energy efficiency, renewable energy, distributed generation, electric vehicles, storage, smart grid, and other technologies proliferate. Increasingly, the challenges presented by these new trends require interdisciplinary solutions that incorporate an understanding of policy, economics, and business, in addition to understanding the capabilities and engineering constraints of different technologies.

To address this new reality, UC Davis is leading the way in developing an innovative new model of interdisciplinary graduate education to train tomorrow's leaders in the energy sector. Developed in 2014, and currently pending review by the University of California system, UC Davis hopes to launch its new Energy Graduate Group in 2016. The program will award M.S. and Ph.D. degrees in one of two tracks: (1) Energy Science & Technology, or (2) Energy Policy & Management.

Intern Development Program

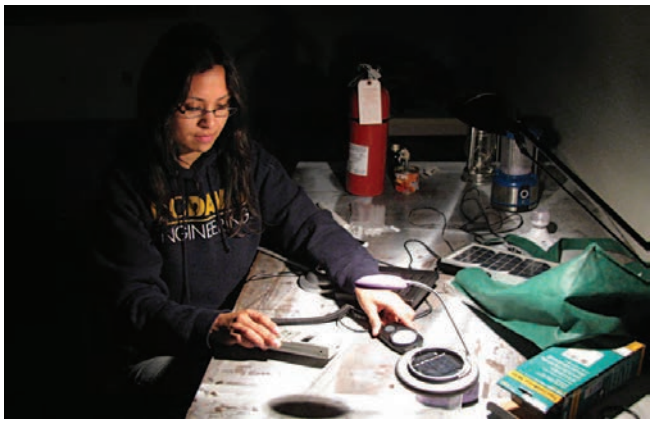
The Intern Development Program (IDP) is a year-long, extra-curricular activity for students engaged in research and outreach activities in energy efficiency solutions. Participation is required for all undergraduate and graduate student interns working at the EEC. The IDP aims to:

- Provide students with a baseline, real-world understanding of: energy efficiency technologies and solutions within the context of the energy services industry, the legislative and regulatory environment, energy-users and energy-providers, and other key stakeholders.
- Advance the professional development and leadership abilities of affiliated students.

- Augment the student experience, beyond assigned projects, with additional experiential learning opportunities and opportunities for research and subsequent publications.
- Expose students to future career pathways and to assist them in career planning and growth.

"Seeing all of the interns grow in a group setting and participating in the interesting lectures/ lecturers really changed the way I approached my day to day life." – *Sandesh Rallipalli —UC Davis Alumni, currently working with Walmart*

The IDP employs a variety of learning opportunities, including guest speakers, student presentations, field trips, guided discussions, and applied trainings over the course of 3 quarters. By the time students complete the IDP, they will have conducted an ASHRAE Level 2 audit of a building, written a white paper on a topic in energy efficiency, and refined a brief presentation on their personal career interests and qualifications. Previous program participants have found employment with a variety of organizations, including Walmart, the Sacramento Municipal Utility District, Wells Fargo, and PG&E.



Office of Naval Research Funding—NEPTUNE

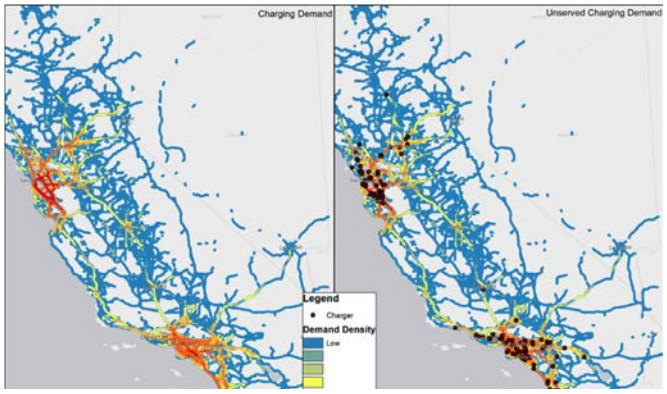
UC Davis has been selected as one of four non-naval universities to receive multi-million dollar funding from the U.S. Office of Naval Research to conduct energy research and train military personnel. The Navy Enterprise Partnership Teaming with Universities for National Excellence (NEPTUNE) program will fund UC Davis, along with Purdue, Arizona State University, and MIT through this prestigious new program.

Navy Secretary Ray Mabus has high hopes that NEPTUNE will advance the Navy's ambitious energy goals, while "simultaneously supporting world-class energy research and professional education for our military personnel. This combination of advanced research with professional development will create an enduring culture of energy innovation within the Navy and Marine Corps." The Navy recognizes that UC Davis is at the forefront of basic and applied research in the areas of energy efficiency technologies and solutions, as well as professional development for both graduate and undergraduate students.

Project 1: Plug in Electric Vehicle Decision Making Data Based Tools

PEV usage is expected to have a major impact on energy sources, grid loads, energy security, local emissions, and greenhouse gas emissions by substituting gasoline driven miles for electric vehicle miles traveled (eVMT). The first direct impact of both battery electric vehicles (BEVs) and plug in electric vehicles (PHEVs) is electric charging loads. The spatial and temporal patterns of the grid loads are an outcome of the PEV market and PEV usage.

The goal of this project is to use and combine existing datasets, collected by other PH&EV center projects, to create and improve analysis tools for PEV usage and EV infrastructure location and usage in order to estimate the impact of different vehicle models, infrastructure scenarios, and policies on reducing internal combustion engine (ICE) miles, increasing EV miles, and strengthening the total market for plug-in vehicles. The analysis tools will focus on the demand for electricity and greenhouse gas reduction forecast for policy and planning, including fleet management and policy analysis. These modeling tools would specifically help the Navy design an optimum PEV fleet vehicle and charging infrastructure strategy.

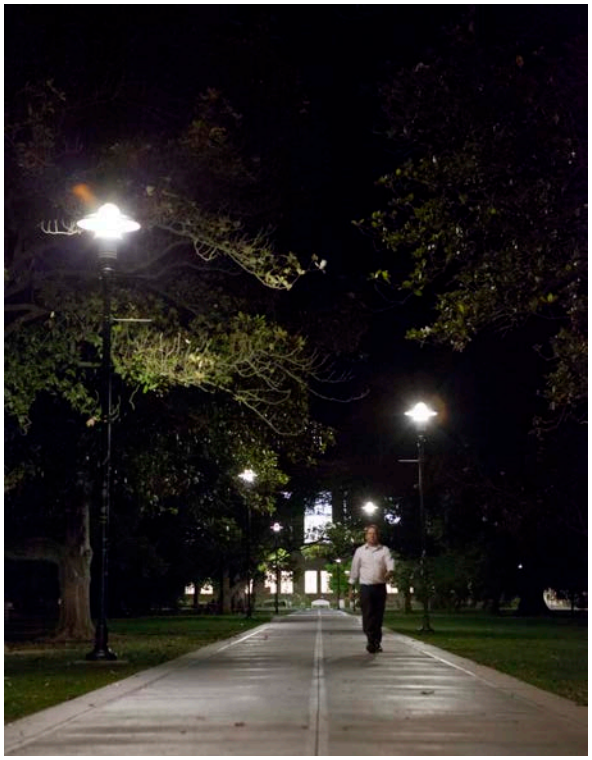


Simulated statewide charging demand based on current vehicle locations and ranges. Left figure shows potential scaled demand from current vehicles. Right figure shows how much demand is met by current chargers.

Project 2: Occupancy Sensing for Lighting Controls in Outdoor Applications

Occupancy-based lighting controls are clearly shown to be an effective strategy to mitigate energy waste and light pollution during long periods of inactivity, generally associated with illuminated outdoor environments. The CLTC, with the support of the California Energy Commission and Investor Owned Utilities, has repeatedly and consistently demonstrated 50 to 60 percent energy savings with the use of occupancy-controlled, adaptive lighting for parking lots, parking garages, building perimeters and other related outdoor lighting applications.

In practice, most sensor-controlled, exterior, adaptive lighting approaches use the integration of dimmable, LED lighting technology with passive infrared (PIR) motion sensors that allow the luminaire to adjust between 100% and 50% power depending on occupant activity. However, existing PIR sensors applied in outdoor applications are simply indoor devices transferred to the outdoor environment. Many of these sensors have a fairly limited range of motion detection, usually up to distances equal to the mounting height of the sensor. While this detection range is effective for indoor applications, it is very limiting for outdoor applications, such as parking lots,



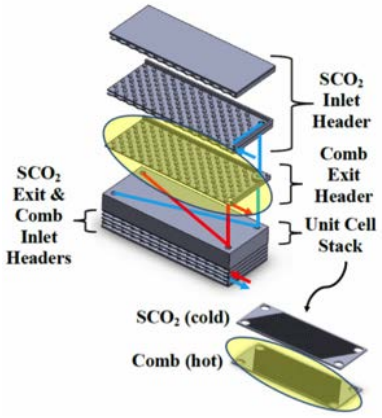
which typically have much larger luminaire spacing and mounting heights. Moreover, traditional PIR sensors are often unable to accurately and consistently detect occupants under very hot or cold outdoor conditions, when the outer temperature of moving people is close to the temperature of outdoor objects.

The proposed project is aimed at developing new, improved strategies and technologies for occupancy sensing in outdoor applications, which will address the shortcomings of existing solutions. The review of existing strategies and technologies will cover a variety of occupancy sensing proxies, such as passive and active infrared sensing, ultrasonic sensing, and microwave sensing. The formulation of new strategies will also consider sensing approaches from other industries that could be used to sense pedestrians and vehicles, such as video cameras and lasers. The most promising new strategies and/or technologies will be implemented in the form of laboratory prototypes and will be tested at UC Davis facilities.

Project 3: High Performance Recuperators for Waste Heat Recovery Cycles

Waste heat recovery from ship systems provides an attractive opportunity for an emission free and low-cost energy resource on board, that can be used for either additional electric power generation or for cooling/air conditioning needs. Crucial to recovering waste heat for several applications is an efficient recuperator, which extracts heat from the gas turbine exhaust and transfers it to the secondary cycle working fluid. The goal of this project is to develop an experimentally-validated design of a compact recuperator for sCO2 power cycles. The principles used in the recuperator design could also be used in the design of low backpressure heat recovery units for use in absorption/adsorption cycles and other applications. The project objectives are to:

- Establish a simplified thermal, fluidic, and mechanical model to design the recuperator;
- Validate the mechanical integrity and thermofluidic performance of a chosen design from the model output based on laboratory-scale experiments; and
- Optimize the design of the recuperator based on realistic constraints of system backpressure



An exploded view of a microchannel primary heat exchanger architecture for indirect fossil sCO2 cycles. Depending on the required capacity, the length and width of the design can be expanded to include more unit cells.

Project 4: Portfolio-level Energy Auditing and Decision-making Methods & Tools

Small and medium-sized buildings have historically been a hard to reach market to implement deep energy efficiency retrofits. The complexity of the current market offerings and a lack of clarity regarding the available whole building integrated retrofit options, produces uncertainty in the marketplace, which ultimately paralyzes the potential consumers and constrains the amount of comprehensive, quality, cost-effective projects that are being done.

While a number of piecemeal solutions exist, which have been successful to some extent, there is a need to comprehensively reevaluate the retrofit process in order to transform the market. This project aims to facilitate the transformation by addressing a critical step in the process: standardizing and lowering the cost of the energy audit process, method, and analysis used by industry.

A central part of the market transformation strategy is the development of portfolio-level, energy auditing and decision-making methods and tools. The EEC has developed a preliminary set of methods and analysis tools for building audits and retrofit recommendations focusing on K-12 schools and convenience shopping centers over the last two years, funded by the California Energy Commission. This project aims to expand the preliminary methods and tools to encompass a broader variety of small and medium commercial buildings. In addition, audit methods and tools will be expanded to include water measures and deployment of distributed renewables.

The outcomes of the project will include:

- Expanded methods for building energy and water audits to encompass a significant share of the small and medium commercial buildings sector.
- A robust database of lighting, HVAC, envelope, plug loads, and water efficiency technologies applicable to the small and medium building sector.
- Methods for analyzing building energy and water data and providing retrofit recommendations.
- Automated tools for portfolio-level building energy and water data analysis, visualization, and reporting.
- Methods to integrate building energy data into the "Universal Data Platform" architecture being developed by the Center for Water-Energy Efficiency.

Solar Decathlon Success

Under the leadership of Frank Loge, Professor of Environmental and Civil Engineering and Director of the Center for Water-Energy Efficiency, UC Davis students competed, for the first time, in the U.S. Department of Energy's Solar Decathlon in October 2015. During the 20 months of preparation and competition, team "Aggie Sol" devoted their efforts to providing affordable, sustainable, zero-net energy housing for farm workers. Working at the intersection of agriculture, energy, economic, and social issues, the team designed and built a home to address the chronic problem of a lack of quality affordable housing in the state.

Opening Ceremony for the U.S. Department of Energy's 2015 Solar Decathlon.

Innovations

- The Aggie Sol home is approximately 995 square feet and relies on innovative approaches to heating and cooling. The team's "Night Sky" system uses evaporative cooling to passively chill water during the evening for use in an in-floor radiant cooling system during the day. Home heating is accomplished by passive solar heat gain, in addition to high-efficiency electrical water heaters powered by solar photovoltaics.

- A highly insulated and sealed building envelope, combined with the high thermal mass provided by concrete floor underlayment, reduces heating and cooling demands and helps to maintain even interior temperatures throughout a 24-hour cycle. A graywater heat recovery system supplements the Night Sky system and reduces the home's energy loads by approximately 15%.

- The home's butterfly roof works in conjunction with the Night Sky system, capturing, collecting and directing the system's water to an insulated storage tank. Water lost through evaporation is made up for by the roof's capture of rainfall. On an annual basis, the home is anticipated to generate a water surplus based on rainfall capture and reuse as well as graywater capture and reuse, thus not adding to ongoing water supply stress in the state.

- In-line structural framing techniques reduced construction materials by 20% compared with traditional framing.

- The need to reduce interior contaminants was frequently identified as a desired feature during preliminary research and design. The team's focus on farmworker needs resulted in the inclusion of a "mud room," where residents returning from a days work can shower and change clothes prior to entering the main living areas of the home. This space could easily be adapted for non-farm worker use into an additional small bedroom, study, or storage space.

Student Participation and Support

The Aggie Sol home was the result of a campus-wide, multidisciplinary effort. The nearly 300 participating undergraduate students, graduate students, and faculty came from a huge range of academic backgrounds, including design, engineering, sociology, business, and communications. Additional faculty and staff assisted from the Center for Water-Energy Efficiency, Institute of Transportation Studies, Plug-In Hybrid and Electric Vehicle Research Center, Western Cooling Efficiency Center, California Lighting Technology Center, Design and Construction Management, Safety Services, and other units. Campus Utilities employees and community volunteers also assisted the core group of fifteen students as the construction period drew to a close.

A goal of the UC Davis team was for the Aggie Sol home to be designed and built entirely by students. With minor exceptions for specialized areas of construction, such as electrical wiring, the team realized this goal. Designing and

building the home on campus was a tremendous experiential learning opportunity for students and introduced many of them to the building design and construction industries for the first time. As a result of their involvement, many students have developed an interest in related fields and revised their career goals.

Aggie Sol received substantial financial support from the University including the Provost; the Energy Efficiency Center; Deans of the College of Engineering, Agricultural and Environmental Sciences; Humanities Arts and Cultural Studies; Social Sciences; Graduate Studies; Graduate School of Management; the Vice Chancellor of Student Affairs; Vice Provost for Undergraduate Studies; and the Energy Institute. The team also received important cash support from Heising-Simons Foundation and PG&E, as well as in-kind support from Honda, Sunpower, Weyerhaeuser, James Hardie, Bosch, Nexus eWater, and many others.

Competition Results

Twenty teams were invited to participate in the 2015 Solar Decathlon. Six teams dropped out for various reasons, including lack of funding, and fourteen teams competed in this year's competition. The Solar Decathlon, as the name implies, involves 10 contests, including market appeal, architecture, engineering, communications, comfort, appliances, and the level of energy produced versus energy consumed (energy balance).

UC Davis' Team Aggie Sol set out to show that zero-net energy construction could be affordable and attractive. The team succeeded, tying for first place in the competition's affordability contest. Team Aggie Sol also tied for first place in the commuting contest.

In other competition results, Team Aggie Sol placed third in the energy balance competition and fourth in architecture. Overall, UC Davis placed seventh in the competition.

"Our team set out to balance high quality, attractiveness and affordability. In winning first place in affordability and fourth place in architecture, I think it's clear that the students met and exceeded their goals for the competition." —*Frank Loge, Professor of Environmental and Civil Engineering and Director of the Center for Water-Energy Efficiency*

Looking Ahead

The Team believes it is possible to provide quality housing, at below market-rate prices, that will comply with California's pending mandate for ZNE housing, if creative thinking and attention to design are applied. With affordability and mass-market potential in mind, the Aggie Sol team chose readily available and standard construction materials for use in the home. Now several builders and growers have reached out to explore ways to take this home design to market. With the competition over, the Aggie Sol home is back on campus awaiting approval of a permanent location, where it will serve as student housing and be available for research, monitoring, and public tours.

The Team's entry into the 2015 Solar Decathlon is UC Davis' first visible step in addressing issues of economic, environmental, and social problems in affordable ZNE housing for the state and across the country. Team Aggie Sol hopes to further refine the design and construction of affordable, agricultural worker housing and has submitted a bid to compete again in the 2017 Solar Decathlon.

Aggie Sol Solar Decathlon House.

California Community Colleges Collaboration

In December of 2014, the Energy Efficiency Center (EEC) and the Chancellor's Office of the California Community Colleges began a partnership with the mutual goal of improving opportunities for entry-level employment in the energy efficiency and building management fields. The EEC and colleagues at the California Lighting Technology Center and Western Cooling Efficiency Center first undertook a curriculum gap analysis in which researchers analyzed the current Career Technical Education (CTE) courses and programs across the state in order to uncover areas in which further EEC involvement may be able to improve the career outcomes for students through improved instructor training, increased access to field technology, and better networking opportunities with future employers. The following is a summary of two of the projects that arose as a result of the gap analysis, specifically in advancing the HVACR workforce.

Focusing on the HVACR Workforce

There is a growing awareness that proper installation and maintenance techniques are critical to managing heating, ventilation, air conditioning, and refrigeration (HVACR) energy use in homes and businesses. This has led to various studies into the technical requirements of these services, but insufficient attention has been paid to some of the other critical components, such as the effectiveness of skilled HVACR tradesmen and women who provide these services—contractors and technicians. These workers are essential to energy efficiency because they are the most direct link between the technology and the end user.

Project 1: Improving Career Development

Unfortunately, the current HVACR workforce tends not to be well equipped or motivated to advance energy efficiency goals. In some cases, training is lacking, as many technicians receive no formal training, and for others, training is insufficient. However, it is often the case that technical training is not the issue; rather there is a *reputation* of these workers being uneducated, unsophisticated, and even lacking in integrity. The emphasis is on completing the job quickly, and not necessarily on providing a solution to the customer, or on saving energy. This has led to unfortunate outcomes: nine out of ten residential AC replacements completely ignore the building code; some evaluations have even found no savings or even negative savings in ratepayer-funded quality installation and maintenance programs; and two-thirds of economizers in the field are non-functioning (in fact, 30-40% are intentionally disabled).

Part of the reason for these outcomes is that HVACR service is often considered a "low-status" career. The work is seen as physically exhausting and the mental demands of the job tend not to be recognized, valued, or nurtured. It is a field that technicians tend to "fail into," rather than aspire to. In fact, people are retiring from this career faster than new recruits are entering, leading to a workforce gap.

The California Community College (CCC) district, and their 26 campuses that offer HVACR Career Technical Education (CTE) programs, face a serious challenge. The need for skilled HVACR workers is large and growing, and there is a growing recognition within the district that the "green jobs of the future" are a unique opportunity for which they must prepare students. But if the career is considered undesirable, it will be challenging for CCC to recruit the numbers of students that they need—not to mention recruit the kinds of students who have the required aptitudes and attitudes.

Center Research

The EEC Behavioral Research Group has been tasked to help identify a strategy to address these issues. Researchers have recently concluded a set of interviews and focus groups with HVACR technicians, contractors, CCC instructors, high school counselors, and employers. Our primary research finding was that the limitations described above are not intrinsic, and do not do justice to the important work that these individuals are carrying out. HVACR work often requires creative problem-solving, helping people by solving their problems and keeping them safe and comfortable, and combatting climate change. Workers in the HVACR trade can make a very good living, and the relatively high starting salary can provide for a comfortable family living wage. In addition, there are well-defined pathways for advancement, and most employers are willing to provide training necessary for advancement.

Despite the significant rewards of this career, most people (including high school students and their parents, teachers, and guidance counselors) are not aware of these benefits. Center researchers determined that the conventional approaches to career recruitment do not tend to be effective. We theorized that outreach to high school graduates must be targeted to students with appropriate temperaments/interests, emphasize the relevant rewards of the career in a way that students can connect with, and should be provided by someone they can imagine being in a few years.

After completing the interviews, Center researchers conducted a series of focus groups with the same categories of stakeholders to further articulate how best to conduct an outreach campaign. We concluded that conveying the benefits of the career would be much more effective in the form of individual technicians telling their own stories of their career paths, including vividly sharing considerable challenges they have had to face, and what it felt like when they ultimately prevailed. We identified the pros and cons of different media for this message—such as online videos and social media—and ways to combine these messages into a broader outreach campaign.

> "…The techs if you look at them, the exterior, a lot have beards, long hair, tattoos, they tend to have vices a lot of people don't approve of, smoking drinking drugs, and the people, parents, teachers, authority look at these people, my kind of person, as destined to fail. … But then they succeed, make a good living and have a good life, against what was seen as the odds…this is actually a vindication. Most technicians are proud of that, wear it as a badge of honor….feel what they're doing is important and difficult in a lot of ways, physically and intellectually, and they're very proud of what they do by and large." —*An Interviewed HVACR Contractor*

Developing this workforce of the future is critical to achieving the emissions reduction goals set by California. In 2016, Center researchers will develop an outreach campaign, including producing a series of short videos and piloting the campaign with a few high school / community college partners.

Project 2: Improving HVACR Credentialing

California's buildings exhibit significant shortfalls in the quality of installation and maintenance of HVACR systems, presenting a major barrier to achieving the state's energy efficiency goals set by AB 32, the California Global Warming Solutions Act. In compliance with AB 32, 100% of HVACR systems in California are required to be installed to quality standards by 2020 and optimally maintained throughout their useful lives. Among the range of barriers to meeting this mandate, studies point to HVACR workforce issues that can be addressed.

Both basic and advanced industry certifications are necessary ingredients to achieving consistently high performance by the HVACR workforce. In addition, the requirement for industry certification is well documented as a prerequisite for HVACR quality installation and maintenance. More than 150 industry-recognized, standards-based, HVACR installation and maintenance competencies have been defined for workers in

this industry. However, only 33% of the state's 58,000 HVACR workers hold an industry certification of any kind. While Apprenticeship programs provide workers with standards-based industry credentials, other training providers, including the community colleges, are less consistent in producing entry-level workers with such credentials. At the same time, it's not clear that HVACR employers actually value industry certifications. A study of 284 HVACR job postings in the San Francisco Bay Area and Los Angeles County showed that NONE of the 150 industry-recognized certifications were listed as required or desirable qualifications for the job. This is a "chicken and egg" situation, in which new technicians do not acquire these certifications because employers are not looking for them, and employers are not looking for them because new technicians do not hold these certifications. This must be overcome through policy and industry efforts, in order to meet the State's goals. Thus, the challenge is threefold: (1) to ascertain what Knowledge, Skills, and Abilities (KSAs) are most valuable in meeting the state's mandates, (2) to determine which industry certifications among the 150 are most appropriate for which segments of the HVACR workforce, and (3) to inform education, training, and awareness/communications initiatives, which together will drive employment of a fully-qualified HVACR workforce.

Center Research

Research is currently underway for a three-phase approach to meeting the above challenges. Managed by the UC Davis EEC in collaboration with Energy Marketing Innovations and the Western HVAC Performance Alliance, this research project will:

- Catalog the top six industry credentials including learning objectives, target audiences, KSAs targeted, prerequisites required, and credential achieved.
- Define industry value of student outcomes, training, and credentials.
- Correlate hiring priorities to student learning outcomes represented by KSAs.
- Identify barriers to widespread adoption of training and credentials.
- Identify strategies with highest probability of breaking through those barriers.
- Determine key stakeholders to support HVACR training market transformation.

- Characterize the support employers would be willing to provide to employees seeking credentials.
- Identify evidence employers would require to prove the ROI of supporting current employees obtaining credentials.

The research methodology includes research into the 150 industry-credentials to determine which are most relevant for entry-level workers, deconstructing the most relevant credentials into KSAs that can be evaluated through primary research with an expert panel, and multiple iterative rounds of discovery with a broad-based industry panel, using the "Delphi" research technique. Conclusions and programs will be used to create an industry awareness and communications plan. The outcome will align education, training, hiring, and continuing professional development with industry standards for a workforce that achieves AB 32 and SB 350 energy efficiency mandates related to HVACR.

Market Transformation of Commercial Building Audits and Retrofits

Achieving broad-scale adoption of comprehensive energy efficiency retrofits in our State's building stock requires a market transformation of the existing service model. UC Davis is developing a consortium of private and public sector stakeholders seeking to transform the market for building retrofits of small and medium sized commercial buildings (SMBs).

Energy Efficiency retrofits in these types of buildings have historically been hard to achieve. The owners and occupants of these buildings do not typically initiate retrofits due to lack of resources (time and capital) to research, manage, and procure efficiency services. Often efficiency does not factor into their core business. The issues are further compounded by market barriers such as information asymmetry, and split incentives that exist between the owners and tenants. The only segment of these buildings that is easier to reach, tends to be owner-occupied, where the owner owns a large portfolio of buildings.

> The term market transformation is the strategic process of intervening in a market to create lasting change in market behavior by removing identified barriers or exploiting opportunities to accelerate the adoption of all cost-effective energy efficiency as a matter of standard practice. http://aceee.org/portal/market-transformation

From the perspective of service providers (such as ESCOs), the retrofits in SMBs are not large enough for their business models to work and therefore limit their service offerings to larger buildings and portfolios of buildings, particularly those owned and occupied by the public sector. Due to a dearth of market-based solutions, the SMB market is primarily addressed by utility programs that are typically delivered at no upfront cost to the customer. While utility programs have been successful in reaching customers, limited program budgets and high costs associated with the current models have made it difficult for these programs to achieve deep, scalable energy efficiency in SMBs.

Achieving broad-scale adoption of comprehensive energy efficiency retrofits in the SMB market requires a

transformation of the existing service model across all key stages of the retrofit cycle. Research over the past 4 years, by the EEC and its affiliated centers, highlights five key areas, that when addressed could facilitate a transformation of the S&M market. The areas are:

1. Establishment of a cost-effective, standardized approach to auditing, analysis, and retrofit selection;
2. Presentation of "efficiency opportunities" as potential actionable items as opposed to prescriptions;
3. Development and deployment of innovative business and financial models;
4. Development of cost-effective and broadly accepted measurement and verification practices; and,
5. Affecting efficiency culture through community engagement.

Leveraging the successful model that was developed in partnership with the California Conservation Corps (CCC) where entry level corps members were used to audit K-12 buildings, the EEC has been working with community colleges, and university and high school students to further expand and standardize the process for training and development of an "entry level" workforce that can deliver basic energy audits (ASHRAE level 2 equivalent) and facilitate retrofits at scale, and at a very low or no-cost to the customer.

Since the technologies that are typically installed in SMBS are not very complex, the hypothesis is that a well-trained "entry level workforce," trained in standardized data collection processes with access to analysis tools, can play a critical role in stimulating the market place. The EEC has been developing and integrating into this, an end-to-end analysis and portfolio management software platform that:

- Offers an easy to use interface for data collection;
- Standardizes high quality audits and recommendations of energy conservation measures to deploy;
- Provides access for contractors and financial services to bid on projects and connect with customers;
- Integrates opportunities for financing, incentives, and rebates that will provide necessary funding for all aspects of the retrofit; and,
- Creates a secure centralized database that will track and analyze the savings generated by the retrofit project for individual and global decision-making.

While the preliminary focus of this work has been on K-12 education buildings, the platform can be easily expanded to other geographic locations (to schools outside of California) and to other building end-uses (offices, hotels, restaurant, etc.). The more end-users and building owners that use the platform, the more the platform will continually be improved in terms of the recommendations and the accuracy of the predicted savings. Additionally, this platform will be a source of unprecedented amounts of data, with which stakeholders (including researchers and policymakers) can make informed decisions.

The EEC is building upon its most recent efforts on this topic in 2015 into 2016 and will continue to collaborate with the following organizations:

As of November 25, 2015, the EEC has generated 427 reports for K-12 schools that have been audited by the CCC. Many schools are using these produced reports (and pre-filled forms) to submit their expenditure plans for California Energy Commission approval. Calculations show an average annual savings potential of over 80,000 kWh and over $15,000, depending on size of buildings, with an average projected savings of 20-40%.

- California Conservation Corps (CCC) – designing, refining, and conducting trials of streamlined on-line mobile survey collection tools and automated analytics and report generation;
- Chancellor's Office California Community Colleges (COCCC) – understanding the market size and training needs for an expanded workforce development of entry level auditors;
- San Diego Gas and Electric Company (SDG&E) – identifying the energy savings opportunities and barriers specifically for restaurants;
- Pacific Gas and Electric Company (PG&E) – identifying the energy savings opportunities and barriers for small-sized buildings on university campuses;
- Various High Schools in Northern California – piloting the use of building science curriculum to train the next generation of energy efficiency auditors; and
- United States Navy –identifying the energy savings opportunities and barriers for Navy bases around the United States, with a specific initial emphasis on California and Hawaii.

New Approach to Realizing Energy Savings

There is frequently a gap between the way things are supposed to work, and the way they actually work. If California and the rest of the nation are going to meet goals for reduction in greenhouse gas emissions, such gaps must be minimized. Many of these gaps are caused by either a mismatch of technology and human factors related to end users or providers, or by institutional or organizational structures that can impede solutions. We need to consider realistically whether or not efficiency solutions (such as technologies, policies and programs, behaviors, and best practices) are really meeting our objectives: are they providing "realized" savings? Research must focus directly on identified gaps and on what is keeping us from systems that perform optimally in the real world. Importantly, these types of problems are neither intractable nor insoluble. The challenge is recognizing the gap and identifying practical, appropriate solutions. These solutions will take many forms, including technical, policy, and behavioral.

An Example of Unrealized Savings—(Non-) Compliance with Title 24

An example of unrealized savings can be found in the rate of compliance with the State's Building Code—Title 24. Title 24 is one of the most progressive state energy codes in existence, and it is on a trajectory to begin requiring Zero Net Energy homes by 2020. Part of the uniqueness of Title 24 is its comprehensiveness and requirements for verifications and acceptance tests. Unfortunately, if Title 24 is not well integrated into the industry that delivers buildings, this comprehensiveness can be a barrier from complying with the code. For example, many contractors choose not to take out a building permit so that they do not have to do everything required to comply with the code. It has been estimated that as many as 95% of residential HVAC replacement jobs never comply with, nor verify, the energy efficiency measures required by Title 24. If they do not go through the compliance process, which starts with taking out a permit, they are not likely to install the energy efficiency measures included in the code, nor verify that the installation was effective.

> No matter how well technologies perform on the computer and in the lab, if they are not well suited to the habits, needs, capabilities, interests, motivations, and understanding of their users, they will not perform as effectively in the field as they did on the drawing board.

UC Davis Energy Efficiency Center (EEC) researchers believe that there are substantial behavioral elements to this problem, and conducted a simple survey of building contractors throughout the state to gauge contractors' assessment of the risks of getting caught without a permit, and the reasons for opting to take the risk. Researchers found that contractors, for the most part, do not believe that there is a credible threat of getting caught without a permit. Over eighty percent of contractors believe that they would definitely or probably not be caught. They also believe the consequences of being caught without a permit are not substantial—86% felt that the consequences would be a small fine, requirement to go back and take out a permit, or other such consequence. The reasons contractors would take this risk are primarily financial: half of respondents felt that they would either lose a bid to someone who was not including the expense of taking out a permit, or would be forced to lower their own bid to be competitive.

Survey results illustrate a gap between perception and reality. The perception is that Title 24 provides huge savings across the state. The reality, however, at least for residential AC replacements, is that the requirements are almost routinely ignored. Research indicates that simply making the code more stringent will not fix this problem, and may, in fact, further reduce compliance rates due to the code becoming more and more difficult to comply with. It may be beneficial, for example, to reevaluate the complexity of the code. Removing measures and verification steps may reduce the potential

energy savings for each home, however, it may also dramatically improve compliance rates. This tradeoff may be worth it, as the resulting engagement by contractors and homeowners would not only increase the fraction of homes in compliance, but it would also build a stakeholder network that might be encouraged to push the envelope even farther by installing more than the required efficiency measures.

Establishing the Realized Energy Solutions Collaborative

EEC is assembling a research collaborative, focused on understanding and closing the gap between expected and realized energy. The Realized Energy Solutions Collaborative (RESC) is intended to be an informal and "virtual" research group at UC Davis, aligning the efforts of interdisciplinary researchers in various departments and research centers across the campus, to focus on the topic of realized energy solutions, and to conduct world-class research and industry engagement that results in commercially available solutions that work in the real world. Project funding continues to go directly to the research centers and individual researchers, but the Collaborative provides a context for these distinct projects to tell a comprehensive "story" that will help to inform and drive policies, programs, market innovations, and research roadmaps.

RESC plans to draw on an esteemed list of affiliated faculty and researchers from the UCD Energy Centers and elsewhere across the campus to bring together world-class researchers to:

> We must look beyond the traditional economic market barriers and study the psychological, social, and cultural factors that drive behavior. With this knowledge, we can design better technologies, policies, programs, and best practices, and encourage the adoption and effective use of efficient and effective technologies that work in the real world.

- Create the critical-mass and context necessary to attract the attention of potential clients and partners, and share the principles of realized energy solutions;
- Maintain high standards for scholarship, research methodology, and real world applicability;
- Engage with industry stakeholders, policymakers, and the research community, via a specialized portal, to ensure that solutions are making their way into products and policies; and
- Conduct outreach activities—such as organizing events, and developing reports—to provide the context for projects, highlight the synergies between projects, and make all aspects of the work accessible to sponsors, partners, and the general public.

Zero Net Energy in West Village and Beyond

California's Long-Term Energy Efficiency Strategic Plan (CEESP) has set an aggressive goal for all new residential homes to achieve zero net energy (ZNE) beginning in 2020. The UC Davis Energy Efficiency Center (EEC) is working on multiple fronts to help establish a sound foundation for achieving these ZNE goals, including technology advancement and innovative market transformation approaches.

West Village Progresses Toward Zero Net Energy

UC Davis West Village is the nation's largest planned ZNE community. ZNE is achieved when a community generates 100 percent of the energy it uses over the course of a full year. Completing its first phase of development in 2011, West Village continues to work towards its goal of producing 100 percent of the energy it uses by full buildout. Each year, the West Village Energy Initiative tracks progress towards this goal. A report released in October 2015, by UC Davis and the West Village Community Partnership LLC, found the community is 82 percent of its way toward reaching ZNE.

West Village houses nearly 2,000 residents, mostly UC Davis students, as well as commercial businesses/retailers, including several UC Davis energy and transportation research centers. When complete, the 200-acre community will house about 3,500 students, faculty, and staff; and provide retail business space and recreation and study facilities.

Achieving Zero Net Energy goals requires continued research, development and demonstration.

West Village relies on two strategies to achieve the ZNE goal: aggressive energy efficiency measures and on-site power generation. The report shows that during 2013-2014, West Village's 4.1 megawatts of photovoltaic panels produced 102 percent of their expected energy due to a combination of factors, including clearer skies, less dust, and a trial cleaning program. Despite strong production, the panels met 82 percent of the actual demand. Achieving 100 percent ZNE will require reducing demand and possibly increasing photovoltaic production.

UC Davis West Village

The report also details a number of actions that were taken to improve West Village's energy performance, including programs to educate residents about wise energy use and the installation of more efficient pumps at the community pools and spa. The annual report can be found online at: http://sustainability.ucdavis.edu/local_resources/docs/wvei_annual_report_2013_14.pdf

Demonstration of Community Scale Low Cost Highly Efficient PV and Energy Management System

To meet the requirements of Assembly Bill 32, the California Global Warming Solutions Act (AB32), and general need for assured access to reliable sources of energy, California must develop distributed renewable energy sources that provide energy surety for the community, while improving grid capacity and stability through peak load reduction and improved renewable to grid integration.

The California Energy Commission recently funded a project by Dr. Jae Wan Park, an Associate Professor in the UC Davis Department of Mechanical and Aerospace Engineering, to develop and demonstrate pre-commercial, renewable power generators, and energy management and control systems which improve microgrid stability and reduce peak power demands, thus reducing stress on the electric grid. The system microgrid is composed of 100 kW Solexel high efficiency photovoltaic (PV) solar panels, 250 kWh of second-life lithium-ion Nissan Leaf electric vehicle batteries for energy

storage, control and energy management systems, and data collection and storage. The system will be tested at UC Davis' Robert Mondavi Institute for Wine and Food Science, which already employs 120 kW of PV panels and an 800 kW diesel generator, and plans to add an additional 100 kW of PV panels and 250 kWh EES units that will use second-life lithium ion batteries.

The intermittency of renewable power generation from sources such as solar and wind can be a destabilizing influence on the grid in areas of high renewable energy penetration. Adding energy storage and control, grid stability can be maintained by either charging or discharging the batteries to keep the grid voltage and voltage angle (and hence frequency) constant.

This project will develop and demonstrate a microgrid controller and energy management system to improve grid stability and reduce peak electrical load. The control system architecture consists of a three level hierarchical system:

- The first level control is an autonomous frequency and voltage control system to mitigate grid instability at each Distributed Energy Resource (DER),
- The second level control will optimize peak shaving and balance across the loads and DERs using an innovative reduced order state space based constrained controller, and
- The third level control will incorporate stochastic day-ahead power and energy management strategies for Demand Response (DR) and Fast Regulatory Voltage and Voltage Angle markets based on demand prediction and renewable power forecasting.

Second life lithium ion batteries donated by 4R energy (owned by Nissan and Sumitomo corp.). We received 1080 modules (approximately 320 kWh) of second used lithium ion battery modules. These modules come from 20 Nissan Leaf electric vehicles.

Recently, our Smart Home resident family hosted a very special guest… Governor Jerry Brown and First Lady Anne Gust Brown.

Honda Smart Home

The Honda Smart Home (HSH) has been occupied for over one year now and the data is flowing. The most recent blog post states that "the home is packed to the brim with advanced sensors that track the flow of every electron and every ounce of water throughout the home's systems – hundreds of channels of data. This information not only advances Honda's research, but that of our technology, utility and university partners."

Honda has released 200 channels of data – down to a one minute resolution – from April through September 2016. This data, more photos, and blog entries can be found here: http://www.hondasmarthome.com/.

UCDAVIS
ENERGY EFFICIENCY CENTER
University of California, Davis
1605 Tilia St. • Suite 100
Davis, CA 95616