LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

WINTER 2014:
VOL. 12, NO. 3

Long Cycle-Life Lithium-Sulfur Battery
Building Energy Modeling for All
Annex 66
Modeling Tools Available
Retrocommissioning Sensor Suitcase
Small Data Centers
Max Tech and Beyond
Miscellaneous Electrical Loads
Determining Office Occupancy
Plasmonic Energy Conversion for PV
Research Highlights
Sources and Credits

To address the world's most critical energy and environment challenges requires working in many fields of science and technology, as well as with a variety of users and user communities. In the Environmental Energy Technologies Division of Berkeley Lab, our audiences are varied indeed, as you'll see from the array of articles in this issue—battery and automotive manufacturers, fuel cell researchers, architects, building energy modelers, facilities managers and the buildings performance community will all find something of interest in this issue of *EETD News*. Please send us your feedback about what you find useful or not, and what you'd like to read about in these pages.

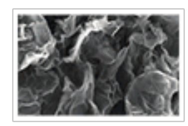
To learn more about EETD's work, please visit http://eetd.lbl.gov.

Don't forget to like us on Facebook, https://www.facebook.com/eet.div.lbnl, and visit our Vimeo channel, https://vimeo.com/eetd.

If you are new to the free quarterly *EETD News*, please subscribe [http://eetd.lbl.gov/newsletter/sub/newsletter_signup.php].

—Allan Chen



EETD News reports on research conducted at Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division, whose mission is to perform research and development leading to better energy technologies that reduce adverse energy-related environmental impacts. The Division's staff of nearly 400 conducts research on energy efficiency in buildings, indoor environmental quality, U.S. and international energy issues, and advanced energy technologies. The newsletter is published online once a quarter. For more information, contact Allan Chen, (510) 486-4210.

The *Center for Building Science News* was published between 1993 and 1998. It covered news of the Division's research in energy efficiency and buildings, the indoor environment, and energy analysis. You'll find all back issues, from Winter 1993 through Summer 1998, available here [http://eetd.lbl.gov/newsletter/cbs_nl/cbsnews.html].

Holistic Cell Design by Berkeley Lab Scientists Leads to High-Performance, Long Cycle-Life Lithium-Sulfur Battery

Battery Could Find Use in Mobile Applications, and Eventually, Electric Vehicles With 300-Mile Range

Researchers at the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) have demonstrated in the laboratory a lithium-sulfur (Li/S) battery that has more than twice the specific energy of lithium-ion batteries, and that lasts for more than 1,500 cycles of charge-discharge with minimal decay of the battery's capacity. This is longest cycle life reported so far for any lithium-sulfur battery.

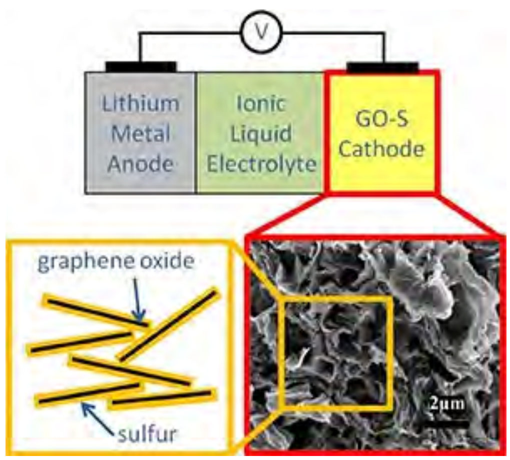
Demand for high-performance batteries for electric and hybrid electric vehicles capable of matching the range and power of the combustion engine encourages scientists to develop new battery chemistries that could deliver more power and energy than lithium-ion batteries, currently the best performing battery chemistry in the marketplace.

For electric vehicles to have a 300-mile range, the battery should provide a cell-level specific energy of 350 to 400 Watt-hours/kilogram (Wh/kg). This would require almost double the specific energy (about 200 Wh/kg) of current lithium-ion batteries. The batteries would also need to have at least 1,000, and preferably 1,500 charge-discharge cycles without showing a noticeable power or energy storage capacity loss.

"Our cells may provide a substantial opportunity for the development of zero-emission vehicles with a driving range similar to that of gasoline vehicles." says Elton Cairns, of the Environmental Energy Technologies Division (EETD)

The results were reported in the journal *Nano Letters*, in a paper authored by Min-Kyu Song (Molecular Foundry, Berkeley Lab), Yuegang Zhang (Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences) and Cairns (Environmental Energy Technologies Division, Berkeley Lab). The research was funded by the U.S. Department of Energy's Office of Science, Basic Energy Sciences, and a University of California Proof of Concept Award.

Benefits of Lithium Sulfur, and Challenges



A schematic of a lithium-sulfur battery with SEM photo of sulfur-graphene oxide material.

"The lithium-sulfur battery chemistry has attracted attention because it has a much higher theoretical specific energy than lithium-ion batteries do," says Cairns. "Lithium-sulfur batteries would also be desirable because sulfur is nontoxic, safe and inexpensive," he adds. Li/S batteries would be cheaper than current Li-ion batteries, and they would be less prone to safety problems that have plagued Li-ion batteries, such as overheating and catching fire.

Development of the lithium-sulfur battery also has its challenges. During discharge lithium polysulfides tend to dissolve from the cathode in the electrolytes and react with the lithium anode forming a barrier layer of Li_2S. This chemical degradation is one reason why the cell capacity begins to fade after just a few cycles.

Another problem with Li/S batteries is that the conversion reaction from sulfur to Li_2S and back causes the volume of the sulfur electrode to swell and contract up to 76 percent during cell operation, which leads to mechanical degradation of the electrodes. As the sulfur electrode expands and shrinks during cycling, the sulfur particles can become electrically isolated from the current collector of the electrode.

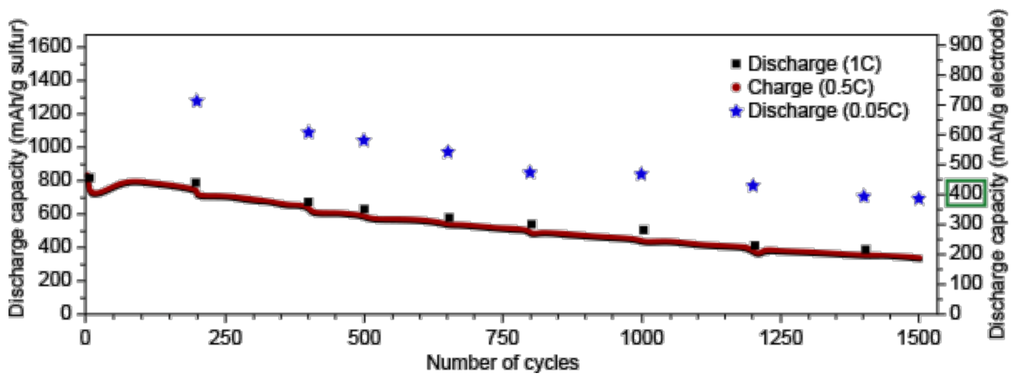
Holistic Cell Design Addresses Chemical and Mechanical Degradation

The prototype cell designed by the research team uses several electrochemical technologies to address this array of problems. The cathode is composed of sulfur-graphene oxide (S-GO), a material developed by the team that can accommodate the volume change of the electrode active material as sulfur is converted to Li_2S on discharge, and back to elemental sulfur on recharge.

To further reduce mechanical degradation from the volume change during operation, the team used an elastomeric binder. By combining elastomeric styrene butadiene rubber (SBR) binder with a thickening agent, the cycle life and power density of the battery cell increased substantially over batteries using conventional binders.

(Read an article from earlier this year [http://eetd.lbl.gov/news/article/56320/sulfur-graphene-oxide-material-for-lithium-sulfur-battery-cathodes].)

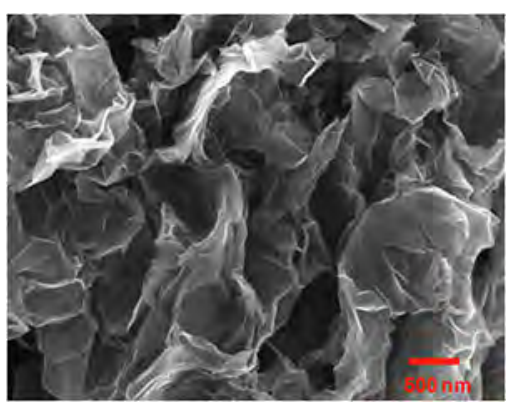
To address the problem of polysulfide dissolution and the chemical degradation the research team applied a coating of cetyltrimethyl ammonium bromide (CTAB) surfactant that is also used in drug delivery systems, dyes, and other chemical processes. CTAB coating on the sulfur electrode reduces the ability of the electrolyte to penetrate and dissolve the electrode material.



Long-term cycling test results of the Li/S cell with CTAB-modified S-GO composite cathodes. This result represents the longest cycle life (exceeding 1500 cycles) with an extremely low decay rate (0.039% per cycle) demonstrated so far for a Li/S cell.

Furthermore, the team developed a novel ionic liquid based electrolyte. The new electrolyte inhibits polysulfides dissolution and helps the battery operate at a high rate, increasing the speed at which the battery can be charged up, and the power it can deliver during discharge. The ionic liquid-based electrolyte also significantly improves the safety of the Li-S battery, as ionic liquids are non-volatile and non-flammable.

The battery initially showed an estimated cell-specific energy of more than 500 Wh/kg and it maintained it at >300 Wh/kg after 1,000 cycles—much higher than that of currently available lithium-ion cells, which currently average about 200 Wh/kg.



Sulfur-graphene oxide Scanning Electron Microscope photo

"It's the unique combination of these elements in the cell chemistry and design that has led to a lithium-sulfur cell whose performance has never been achieved in the laboratory before—long life, high rate capability, and high cell-level specific energy," says Cairns.

The team is now seeking support for the continuing development of the Li/S cell, including higher sulfur utilization, operation under extreme conditions, and scale-up. Partnerships with industry are being sought.

The next steps in the development are to further increase the cell energy density, improve cell performance under extreme conditions, and scale up to larger cells.

—Allan Chen

For more information:

Elton Cairns
(510) 486-5028
EJCairns@lbl.gov

Additional information:

"A long-life, high-rate lithium/sulfur cell: a multifaceted approach to enhancing cell performance," in *Nano Letters*, by Min-Kyu Song (Molecular Foundry, Berkeley Lab), Yuegang Zhang (Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences) and Cairns (Environmental Energy Technologies Division, Berkeley Lab).

This research was funded by the U.S. Department of Energy's Office of Science and a University of California's Proof of Concept Award.

The Molecular Foundry is one of five DOE Nanoscale Science Research Centers (NSRCs), national user facilities for interdisciplinary research at the nanoscale, supported by the DOE Office of Science. Together the NSRCs comprise a suite of complementary facilities that provide researchers with state-of-the-art capabilities to fabricate, process, characterize, and model nanoscale materials, and constitute the largest infrastructure investment of the National Nanotechnology Initiative. The NSRCs are located at DOE's Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge and Sandia and Los Alamos national laboratories. For more information about the DOE NSRCs, please visit their website [http://science.energy.gov/bes/suf/user-facilities/nanoscale-science-research-centers/].

DOE's Office of Science is the single largest supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time. For more information, please visit the Office of Science [http://science.energy.gov/] website.

LAWRENCE BERKELEY NATIONAL LABORATORY
Environmental Energy Technologies Division NEWS

Simple and Elegant Building Energy Modeling for All—A Technology Transfer Tale

> A building owner changes the building's thermostat setting, allowing the indoor temperature to increase a couple of degrees for an entire afternoon. But how much energy was actually saved? To know the answer for sure, the energy actually used must be compared to the energy that would have been used if they hadn't made the change…but how does the building owner find that out?

The answer is provided by a "baseline energy model," a statistical formula that, based on the analysis of previous energy use, takes into account the time of day, the day of the week, and the outdoor air temperature to predict the building's energy consumption as a function of time if the building were operated normally.

Philip Price

When Environmental Energy Technologies Division (EETD) researcher Phillip Price began working with building energy data a few years ago, he discovered that the standard baseline energy models are very simple. "And that makes sense," says Price, "because usually the only useful explanatory variable you have is outdoor air temperature. If your only variables are time and temperature, you may not get much benefit from a complicated model." EETD is a Division of the Lawrence Berkeley National Laboratory (Berkeley Lab).

But he also discovered that the standard approaches have some flaws, so he made improvements. He developed a model that produces more accurate predictions in most buildings, but isn't much more complicated than previous models. He and graduate student Johanna Mathieu published the model in 2011.

Price has worked with statistical models for 20 years at Berkeley Lab. In the early 1990s he became one of the foremost authorities on the spatial and statistical distribution of indoor radon, and co-developed state-of-the-art algorithms for mapping airborne pollutant concentrations using optical remote sensing data.

He turned his hand to statistically modeling electric load data several years ago. While researching for his model development, Price noted changes happening in the industry, which dramatically increased the amount of energy use data available.

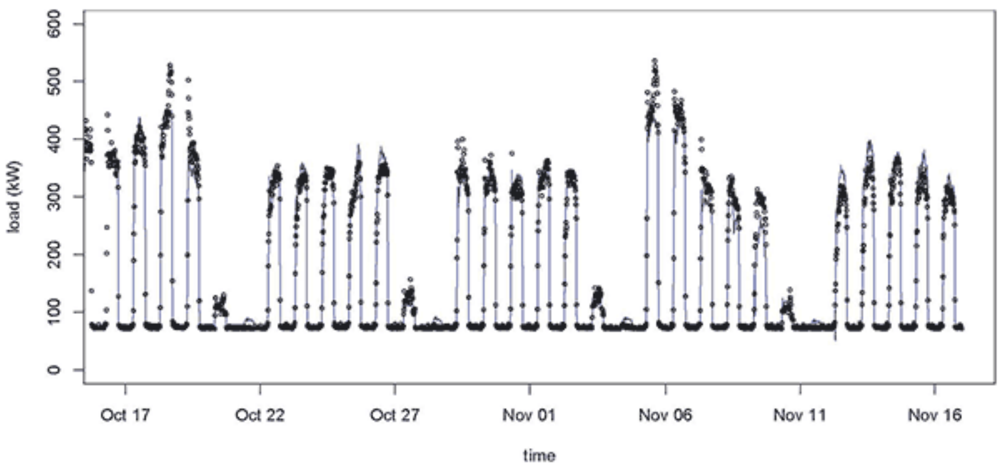
"Until not too long ago, the only energy use data people had were monthly use data," Price said. "Now that we have 'smart meters,' we've started getting more data and that has opened up many possibilities. The idea was to look at what people were doing and see if we could do better—and that effort led to this model."

Looking at energy use in much smaller increments of time led to additional needs for modeling. Price wanted to include a simple way for building designers and operators to measure the outcome of energy efficiency measures looking separately at the effect of temperature during different building occupancy and use scenarios, as well as taking into account the use of many different pieces of equipment and technology.

"What you want in a decent model is something that takes temperature into consideration in a different way when the building is operating and when it is not," Price said. "As an example, suppose we have a night and day that are 75 degrees all the way through. At night, we wouldn't be conditioning the building; during the day, you are cooling. Dependence on temperature is also something that changes," he said.

"Also, even when the heating and cooling systems are operating, there is usually some range of temperature when you don't have to cool or heat. Below that range you need to heat, above that range you need to cool. If the outdoor temperature gets warm enough, at some point the cooling system is working flat out and you can't use more, so energy use stays the same. So rather than a straight-line dependence on temperature, it can be a curvy line," he said.

The model has been helpful to a number of industry organizations that have used his methods as a basis for business functions and tools.



Measurements of energy use in a building (black dots) plotted with electricity load predicted by the LBNL regression model.

Tom Arnold, co-founder and CEO of Gridium, a Bay Area company that helps commercial customers make sense of the flood of energy data provided by smart meters, ran across a paper written by Phil Price about his model and used it to catalyze his work early in the company's history.

"His model was a kernel that catalyzed our work," Arnold said. "I think this is quite common; you get a little bit of government-funded research and it's digested by the private sector," he said.

Arnold said that he needed to find a model that applied time-theory statistics to the energy use issues his customers face, and the model was a simple way to begin approaching it. Now, Arnold's company analyzes data from 110 million square feet of buildings, using Cloud computing to run tens of thousands of modeling scenarios across many servers, providing weekly analysis of building energy performance for customers.

A Berkeley company called QuEST also used the model as a foundation for their work. QuEST works in commercial utility programs to identify energy efficiency measures and verify energy savings.

"I had a research project from the California Energy Commission to develop a measurement and verification tool, so we needed an energy model," said David Jump, principal at QuEST. "We talked with LBNL, Phil, and some others. They had already developed this modeling code for other projects, and we went with this one because we wanted to model energy use on as frequent as 15-minute intervals over the period of a day," he said.

Jump said they started with Pacific Gas & Electric's desktop tool, Universal Translator, which is fairly well known in the energy efficiency industry, and then added measurement and verification capability based on Price's model.

"I introduced our tool at the last ASHRAE meeting, and everyone wanted a copy," Jump said. "Here is a tool that has soup-to-nuts measurement and verification capabilities, all open source. And it basically eliminates the need for highly skilled, high-priced people to do modeling work," he said.

So far, companies that have been using Price's approach have had to write their own computer code based on his publications, but that's about to change: an improved version of the model is soon to be released as part of an open source software distribution.

Price continues to work on baseline energy models, and he is excited about a new approach he is developing.

"The simple model works fine for predicting energy consumption in the near future, but it's not ideal for other applications such as detecting sudden changes in a building's energy consumption pattern," said Price. "The new approach is very well suited to that kind of application, but you pay a price in increased complexity. I think the simple model is going to be around for a while," he said.

—Kyra Epstein

For more information:

Philip Price
(510) 486-7875
PNPrice@lbl.gov

Annex 66 Seeks to Standardize Studies of Occupant Behavior

Tianzhen Hong

It is well-documented that prodigious amounts of energy and money have been saved by energy-efficient building technologies. California alone has saved billions of dollars, prevented tons of pollutants, and avoided having to build additional power plants thanks to its efficiency efforts. Still, the effectiveness of these technologies is dependent on building occupants not only using them, but using them properly. How much of an effect occupant behavior has on energy savings is uncertain, but most researchers agree that it is significant. More than 20 groups worldwide study building occupant behavior, but experimental design and modeling methodologies differ, and many studies lack detailed quantitative analyses.

In recognition of this problem, the IEA (International Energy Agency) Energy in Buildings and Communities (EBC) Programme approved the Annex 66 project at its Executive Committee Meeting in 2013. The project will establish a standard occupant behavior definition platform and a quantitative simulation methodology to use to model occupant behavior in buildings. This standardization will make studies easier to compare and give researchers a deeper understanding of occupant behavior on energy use and the indoor environment.

The Annex 66 project has five subtasks:

1. occupant movement and presence models
2. occupant action models in residential buildings
3. occupant action models in commercial buildings
4. integration of occupant behavior definition and models with current building energy modeling programs
5. applications in building design and operations

Environmental Energy Technologies Division researcher Tianzhen Hong and Da Yan from Tsinghua University, China, are the operating agents for Annex 66. They manage the work of the various participants and supervise the production, financing, and availability of Annex 66 products. Hong is also subtask leader for Subtask D, and will work to integrate that work with the current modeling programs.

At this writing, 56 organizations in 23 countries have expressed strong interesting in participating in the project, which began in November 2013. This preparation phase will continue until October 2014, when its working phase will begin and last for two years. Project results will be reported in 2017.

"To achieve significant carbon reductions and mitigate global climate change, it's necessary to have a deep understanding of occupant energy behavior in buildings," says Hong. "Being able to model and quantify how behavior impacts the use of building technologies and building energy performance using scientific methods is crucial to the design and operation of low-energy buildings."

—Mark Wilson

For more information:

Tianzhen Hong
(510) 486-7082
THong@lbl.gov

Additional information:

Annex 66 website [http://www.annex66.org/]

Lawrence Berkeley National Laboratory
Environmental Energy Technologies Division
NEWS

Buildings, Energy, Greenhouse Gas, Industrial and Policy Modeling and Simulation Tools Available from Energy Analysis and Environmental Impacts Department

Tools and models to find the best way to save energy and reduce greenhouse gas emissions in cities and industries, to follow the transport of pollutants through the environment, and to calculate the cost of power interruptions are among those available on a new Lawrence Berkeley National Laboratory (Berkeley Lab) web site [http://eaei.lbl.gov/tools].

View available simulation tools at http://eaei.lbl.gov/tools

The site [http://eaei.lbl.gov/tools] brings together models and simulation tools developed by the Energy Analysis and Environmental Impacts (EAEI) Department of the Lab's Environmental Energy Technologies Division.

"Our hope is that the site will facilitate greater technical awareness of the many analytical tools we have developed over the years, potentially leading to new opportunities for cooperation among stakeholders and sponsors," said Charles H. Goldman, Leader of the Energy Analysis and Environmental Impacts Department.

The site lists tools according to research area (technology environment, economics), the relevant energy sector (buildings, industry, power transportation, cross-sector).

A search tool in the left hand margin of the page allows users to search for relevant tools by research area, sector, and the type of user who might be interested in the tool: industry practitioners, academic institutions, policy makers, state regulators, and utilities. By checking off the boxes under area, sector, and user type (or research group within the Department), the user can create a customized list of tools geared to his or her own interests.

The search tool helps users go directly to the tool with the capabilities they need, rather than search through a variety of pages.

The variety of tools available is broad and reflects the work conducted by dozens of researchers in the EAEI Department over many years of effort. Included in the 40 available tools are a tool for analyzing distributed energy resources, a utilities tariff analysis, a tool for analyzing energy-efficient retrofit alternatives for commercial buildings, and tools for analyzing the energy efficiency gains and greenhouse gas reductions of various types of measures in a variety of industries including pulp and paper, steel, and textiles.

—Allan Chen

For more information:

Brian Heimberg
(510) 495-8010
BSHeimberg@lbl.gov

Additional information:

Energy Analysis and Environmental Impacts tools and models [http://eaei.lbl.gov/tools]

The Retrocommissioning Sensor Suitcase Brings Energy Efficiency to Small Commercial Buildings

Most buildings in the U.S. don't perform as energy-efficiently as they could simply because energy-using equipment in the building have never been set up to maximize energy performance. Thermostat setpoints are too low or too high, so rooftop units (RTUs) cool buildings down below recommended temperatures, or keep them too warm (or both). Or, there is no difference in the setpoint during hours when the building is unoccupied versus occupied—turning the heat and space conditioning down during unoccupied hours helps lower energy bills substantially. Lights may be left on at night when no one is in the building, or there may be daytime opportunities in spaces that are not continuously occupied.

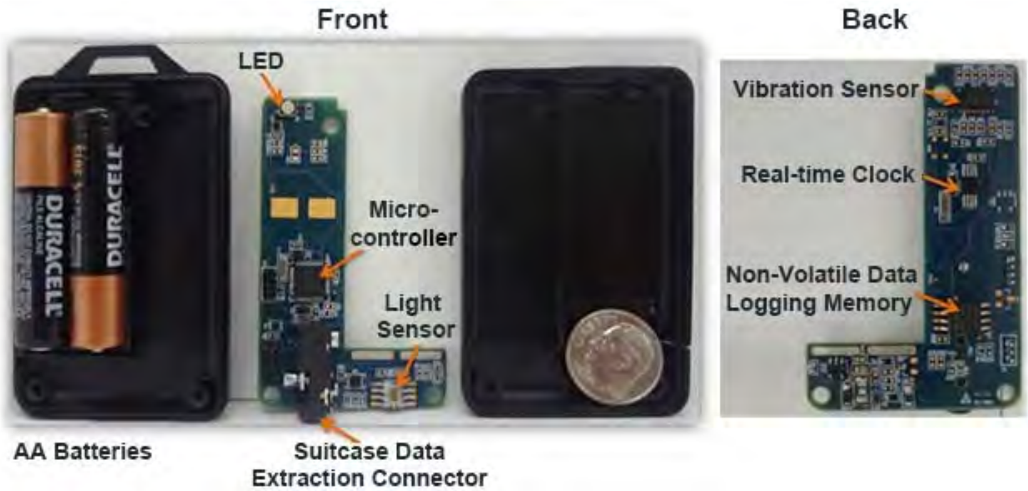
The data module communicates wirelessly with the smart pad, which launches sensors during their installation.

These are only a few of the problems that energy performance professionals see in the field, problems they can correct through retrocommissioning—the process of assessing the energy performance of an existing building, and then tuning its systems, and implementing no or low-cost energy efficiency improvements. When this is done to a new building, it is called commissioning. Research published in 2009 by scientists at Lawrence Berkeley National Laboratory (Berkeley Lab), demonstrated that in a large sample of existing buildings, retrocommissioning could save as much as 15 percent of a building's annual energy use, and pay for itself in less than a year, through the resulting utility cost savings.

In large commercial buildings, where the cost-effectiveness of this process is highest, retrocommissioning is beginning to become more common, thanks to growing awareness of its economic benefits to building owners and operators, as well as a thriving industry of building energy performance professionals.

In smaller commercial buildings efficiency efforts, including retrocommissioning have been hampered by several factors. "Small commercial buildings do not typically have budget or business economics that allow investing in enhancements such as comfort and energy improvements," says Jessica Granderson, a scientist in the Environmental Energy Technologies Division of Berkeley Lab. "They also don't have in-house staff with the expertise in building systems who can perform retrocommissioning or identify improvement opportunities."

Granderson, the Deputy Leader of EETD's Building Technologies and Urban Systems Department, is working with Michael Brambley of Pacific Northwest National Laboratory to develop a technological solution: the Retrocommissioning Sensor Suitcase.

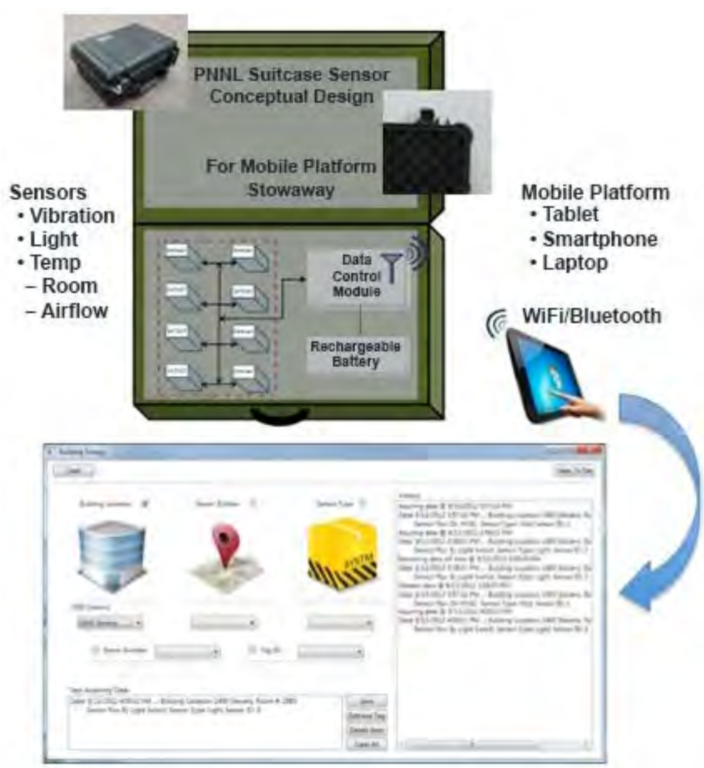


Sensor platform prototype

"The Suitcase," she says, "is a turn-key hardware and software solution that non-experts can use to generate low or no-cost recommendations automatically on how to improve a building's operating costs, comfort and energy performance." The project is funded by the Department of Energy's Office of Energy Efficiency and Renewable Energy, Building Technologies Office.

"The Retro-commissioning Suitcase project is a DOE funded project to reduce the cost of delivering cost effective, energy savings retro-commissioning services to small and medium sized buildings," says George Hernandez, Chief Engineer, Building Technologies Office in the Department of Energy. This project is accomplished by 'embedding' the knowledge and skills of a highly experienced building commissioning practitioner into a scalable hardware and software package that can be easily deployed by a variety of building services personnel to make it easier for building owners and operators reap the benefits and cost savings for building commissioning."

The turnkey under development in this joint Berkeley Lab-PNNL project contains a set of different types of portable, easy-to-install building sensors, a handheld smart pad for documenting the location, placement and sensor type, a battery, and a data control module that can receive and pre-process data from the sensors, which are distributed throughout the building. The data module communicates wirelessly with the smart pad, which launches sensors during their installation. (See Figure 1.)



Downloading the data

The Retrocommissioning Sensor Suitcase is targeted for use in small commercial buildings of less than 50,000 square feet of floor space that regularly receive basic services such as maintenance and repair, but don't have in-house energy management staff or buildings experts. The hardware kit is designed to be easy-to-use by building maintenance staff, or other professionals such as telecom and alarm technicians. The sensors in the suitcase include those for lighting, vibration (for measuring the condition of rooftop units), and various types of temperature sensors for internal and external areas of the building. (See Figure 2 - sensor platform prototype.)

In addition to the hardware kit, the turnkey comprises a software application to collect, process, store, and analyze the data. The kit's user, or a third party such as an energy performance contractor can use this software to generate specific recommendations on what actions to take to reduce the building's energy cost, and improve comfort.

"The Suitcase's user would walk through the building, installing the sensors based on guidance from the hand-held," says Granderson. "Simple instructions make it easy for the user to configure the sensors and document their type, and location using the smart pad."

After a month or so of automatic data collection, the user returns and collects the sensors, plugging them into sockets in the suitcase to download their data. (See figure 3.) Entering other basic information into the suitcase's computer, like energy consumption and costs from the building's electricity bill, allows the software to generate recommendations on how to improve the building's performance, and how much energy could be saved by each measure. It's then up to the building's owner or operator to decide which measures to implement.

Status of Development

"Where we are now is that the proof of concept prototype is complete. We're entering into a second phase of work to test the prototype in the field, and improve it based on what we learn." says Granderson. The development team plans to make the hardware and software design available in the public domain, for transfer of the technology to partners who will move it into the marketplace.

—Allan Chen

For more information:

Jessica Granderson
(510) 486-6792
JGranderson@lbl.gov

Additional information:

This research is funded by the Department of Energy's Office of Energy Efficiency and Renewable Energy.

Identifying Energy Efficiency Opportunities for Small Data Centers

Glossy photos in magazines and on the web tend to portray server rooms as large spaces with gleaming, symmetrical rows of servers on temperature-controlled racks. In reality, however, 57 percent of U.S. servers are housed in small spaces such as server closets and localized data centers, in what are commonly referred to as *small server rooms*. Such spaces comprise 99.3 percent of all server spaces in the United States. In contrast to large, consolidated server operations, which pursue energy efficiency as a strategy to minimize their operational costs, these small, decentralized server operations do not, and because their configurations are site-specific, it is challenging to develop efficiency measures that can be used widely.

Given the great potential for energy savings, researchers from Lawrence Berkeley National Laboratory (Berkeley Lab) investigated how IT equipment was deployed, powered, and operated in small server rooms, and developed strategies to improve energy efficiency. The team surveyed 30 small server rooms across eight San Francisco Bay Area institutions, ranging from high-tech companies to academic and health care institutions, local governments, and a small business.

"We took a half hour to walk through each space with the owner or operator and collect data on how the equipment was configured and run," explains Environmental Energy Technologies Division (EETD) researcher Iris Cheung. "Our hosts also provided background information on the room, to give us a sense of how the current configuration came to be. This helped us to identify potential barriers to energy efficiency improvements."

Common Attributes, Missed Opportunities

A typical small server room; this one at Stanford University

Some commonalities arose as server spaces were surveyed; the most prominent being that most were not originally intended to operate as server spaces, and therefore, the efficiencies inherent in dedicated server spaces were not present. Many also suffered from principal-agent problems, meaning that the utility bill was paid by someone other than the server operators or owners. In addition, server energy use was often not submetered, so server operators received little or no feedback on their energy cost, and therefore had no incentive to pursue energy-efficiency improvements.

Also notable was that company business operations often took precedence over energy efficiency concerns. These priorities were reflected in limited IT budgets that left older, less-efficient equipment in place longer. And even though consolidating the servers could have greatly improved energy efficiency, the motivation to do this was low because often the equipment was not used regularly, they couldn't visualize the potential cost savings, and/or the server owners wanted to keep the equipment close to them.

Not surprisingly, server cooling turned out to be an area that offered potential for great improvement. Many server room temperature set points were lower than necessary, so energy was wasted by overcooling. Some used dedicated cooling systems that ran 24/7, even at temperate climates, while others set the building's cooling lower than it otherwise would be, to ensure that the ambient air was cool enough to cool the servers. Few had separate hot and cool areas to minimize hot/cold air mixing and improve cooling efficiency, as is often the case in large server spaces, and none took advantage of cooler outside air to reduce the amount of mechanical cooling required.

A Closer Look Reveals Significant Inefficiencies

Once the surveys were complete, the team selected four sites-one at Berkeley Lab, one at the city of Walnut Creek, and two at Stanford University-for detailed assessments. "We chose these spaces because they broadly represented other small server room configurations and had high potential for efficiency improvements, good site access, and operator interest."

The goal of assessing those four sites was to examine the IT infrastructure and systems in more detail. Using data-logging power meters on the circuits that supplied power to the equipment, the team measured IT, cooling, and other power-consuming equipment in each space, to determine actual power consumption and efficiency opportunities. To calculate power usage effectiveness (PUE), the researchers measured total server room power use, including lighting, power distribution, and uninterruptible power supply (UPS) losses wherever possible; estimating power consumption or losses if measurements were not possible (see table).

"We found that PUE values ranged from 1.5 to 2.1," says Cheung. "So in the upper range, the server room's total power usage was about twice the amount of power used by its IT equipment."

PUE Breakdown for the Four Sites

Server Room	Stanford, University 333 Bon Air Siding	Stanford, University Alumni Center	LBNL 90-2094	City of Walnut Creek
Cooling, kW	8.5 [1]	5.5 [2]	3.3 [1]	14.9 [1]
Lighting, kW	0.8 [2]	0.1 [2]	0.1 [2]	0.1 [2]
UPS loss, kW	1.8 [2]	1.7 [2]	0.1 [2]	1.3 [1]
Total load, kW	21.3	17.2	10.4	31.3
PUE	2.1	1.8	1.5	2.1

[1] Directly measured
[2] Assumed or estimated

Identifying Energy Efficiency Strategies

Because businesses and institutions using small server rooms often have limited resources, the project first focused on low- or no-cost measures for improving their server room's energy efficiency, which included raising cooling set points and better airflow management. More involved but still cost-effective measures included server consolidation and virtualization, and dedicated cooling with economizers.

Cheung explains: " We found that inefficiencies mainly resulted from organizational rather than technical issues. Because of the inherent space and resource limitations, the most effective measure is to operate servers through energy-efficient cloud-based services or well-managed larger data centers rather than server rooms. Otherwise, backup power requirement, and IT and cooling efficiency should be evaluated to minimize energy waste in the server space. Utility programs are instrumental in raising awareness and spreading technical knowledge on server operation, and the implementation of energy efficiency measures in small server rooms."

Spreading the Word

To reap the significant energy and cost-saving potential for small server rooms, it's necessary to communicate the energy-efficiency benefits (and how to achieve them) widely across the sector. So the team also presented its findings to server room operators, data center energy-efficiency professionals, industry organizations, utilities, and product vendors, with specific efficiency measures that could be applied to other server spaces. Collaborating with Stanford University and the Natural Resources Defense Council, Berkeley Lab also developed a simple and more detailed version of a fact sheet that summarizes energy-saving solutions for small server room owners and operators (see below). In addition, they conducted workshops at data center conferences.

"Much of the inefficiency in small data centers can be traced to a lack of education about energy-efficient equipment and operation among server owners and operators," says Cheung. "By training operators in energy-efficient IT, cooling, and power distribution, and by facilitating increased energy-efficiency visibility, server room energy efficiencies could improve significantly. We hope to build on this work by evaluating more of these spaces, identifying better, cost-effective tools to track server utilization, and by developing case studies that operators can use to increase the energy efficiency of their server rooms."

—Mark Wilson

For more information:

Hoi Cheung
(510) 486-6167
HYCheung@lbl.gov

Additional information:

"Improving Energy Efficiency for Server Rooms and Closets" [http://hightech.lbl.gov/serverclosets]

"Fact Sheet (Web Content): Improving Energy Efficiency for Server Rooms and Closets" [http://hightech.lbl.gov/documents/data_centers/fact-sheet-ee-server-rooms.pdf]

Cheung, H. Y. Iris, Steve E. Greenberg, Roozbeh Mahdavi, Richard Brown, and William Tschudi. 2013. *Energy Efficiency in Small Server Rooms*. California Energy Commission.

Lawrence Berkeley National Laboratory

Environmental Energy Technologies Division

NEWS

Efficiency Entrepreneurs Approaching Max Tech

Smarter power plugs and appliances that can turn electronics on and off according to a homeowner's behavior rather than a fixed schedule. A water heater that delivers water to the different fixtures in the house at temperatures customized for the particular water use. A smarter-than-ever thermostat that knows how to set different temperatures for different rooms in a house. High-pressure water jets that can cut magnetic metal to construct high-precision, high-efficiency motors at lower cost. These are just some of the energy efficiency technologies and prototypes that are being developed and tested as part of the 2013-2014 Max Tech and Beyond [http://maxtechandbeyond.lbl.gov/] Design Competition. The annual competition, which is run by Lawrence Berkeley National Laboratory (Berkeley Lab) with funding from the Department of Energy's (DOE) Building Technologies Office, challenges college students to design ultra-low-energy-use appliances and supports the education of the next generation of U.S. clean energy engineers.

Lin Xia from UC Irvine assembles the electronic components for her team's smart power strip prototype.

Jarrett Kodani and Kok Lim from the University of Hawaii disassembles a pancake-style 3-phase washer motor and measures its physical and electrical parameters for benchmarking.

University of Virginia's Yong Sun builds a prototype of a smart water heater.

Twelve teams from U.S. colleges and universities across the country are currently competing to build and test the most energy-saving prototype. Teams include a faculty lead and at least three students-undergraduate, graduate, or a mix. According to Berkeley Lab's Robert Van Buskirk, who mentors the teams: "As a Department of Energy National Research Laboratory, Berkeley Lab helps the university teams understand the importance of their work as an element of a national technology innovation strategy. We do this by helping them understand the techno-economic yardsticks by which their prototypes may be judged." Berkeley Lab staff discuss with each team their understanding of the "next best alternative" to their technology ideas and how they could beat the competition-by devising a more energy-efficient technology, a more cost-effective one, one that brings greater value to consumers, or some combination of all three.

"The Max Tech and Beyond Project also facilitates the market entry of successful prototypes developed by the teams through its Bridge to Market Program, a collaboration with UC Davis Entrepreneurship Academy [http://gsm.ucdavis.edu/entrepreneurship]," says LBNL's Karina Garbesi, Principal Investigator of the Max Tech and Beyond Project. Last year three of the competition's successful teams—from the University of Maryland (UMD), Ohio State University (OSU), and the University of Nevada, Las Vegas (UNLV)—attended the academy. The academy helps faculty and students understand the business startup process and provides a network to support successful business development.

Zeeshan Mohammad, a UNLV team member in 2012-2013 who attended the UC Davis Entrepreneurship Academy last September, decided to re-enter the competition this year both because of his belief in the competition and how much fun the first year was. "I enjoyed working with a group of people who were as dedicated as myself to succeeding and working hard," says Mohammad. He believes that his work on such a practical, real-life project has boosted his career prospects-and he hopes to see the voltage controller he helped prototype installed in a commercial appliance.

The Max Tech Project is also raising the profile of successful teams and prototypes by showcasing them at DOE's Solar Decathlon Expo [http://www.solardecathlon.gov/]. Two Max Tech teams exhibited in October 2013. The UMD team demonstrated their ultra-efficient two-stage heat pump clothes dryer, which won them first place in last year's Max Tech Competition. The runner-up team from OSU presented their hybrid air/water conditioner, which marries a heat pump to deliver air conditioning with a component that recovers waste heat from the air conditioning cycle to heat water.

DOE is looking forward to this year's teams presenting the results of their prototype development and testing in the spring, with the winners announced in late summer, after final reports are submitted. The competition is already fierce—much fiercer than the Broncos-Seahawks rivalry—so stay tuned! In the meantime, student teams from colleges and universities across the country are strongly encouraged to gear up for the Max Tech Competition for the 2014-2015 academic year by responding to the upcoming request for proposals, which will be available later in February. For more information about the Max Tech Competition, email maxtech@dante.lbl.gov .

Additional information:

Max Tech and Beyond Design Competition [http://maxtechandbeyond.lbl.gov/]

UC Davis Entrepreneurship Academy [http://gsm.ucdavis.edu/entrepreneurship]

DOE's Solar Decathlon Expo [http://www.solardecathlon.gov/]

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Measuring Miscellaneous Electrical Loads in Buildings

'Other' is the fastest growing energy use in residential and commercial buildings—devices such as computers, displays, printers and other office equipment, as well as small household appliances ranging from kitchen electrics like coffee makers, toasters, and mixers to fans, clocks and portable space heaters. To energy researchers these devices are known as miscellaneous and electronic loads (MELs), and about one-third of end-use electricity consumption in homes and commercial buildings is attributed to them.

Hundreds of devices fall under the MELs category, and their energy use is not well-understood, in part because of their great variety, and because the sensing technology to measure these individual loads is expensive ($200 to $300 per metering point) and cumbersome to install.

Researchers in the Environmental Energy Technologies Division (EETD) of Lawrence Berkeley National Laboratory (Berkeley Lab) have teamed with the University of California, Berkeley to study MELs, to better characterize the variety of MELs and estimate their load growth, and to develop better inexpensive technologies for monitoring them. EETD's Steven Lanzisera and Rich Brown have been leading the effort to decipher MELs impacts on buildings

Understanding and reducing the energy use of MELs is a significant problem. The buildings industry is working towards designing, building, and operating very low to net-zero energy using buildings, and the load growth of MELs is pulling energy use in the wrong direction. Knowing which devices use the most energy, and what their load profiles look like—that is, how their energy use fluctuates throughout the day—will help researchers, and ultimately, manufacturers, building operators and homeowners, understand how to better manage the energy use of MELs.

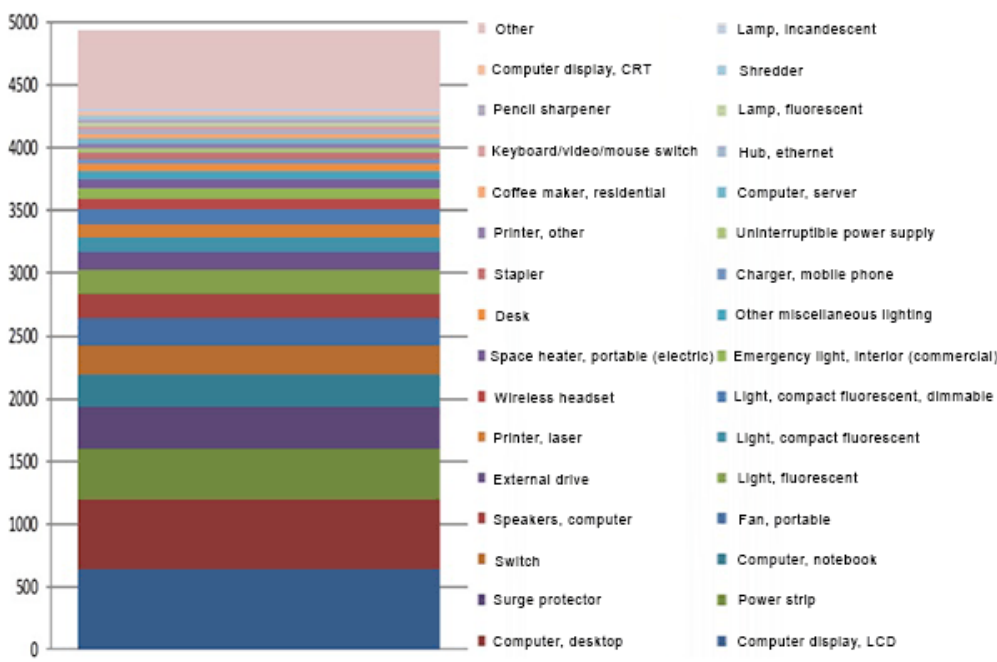


Figure 1. Miscellaneous electric loads (MELs) distribution in a sample office building.

Data Collection Systems Used in Recent MELs Metering Studies

A connected, networked building would give energy managers data that could help them better manage energy use efficiently, and maintain comfortable, healthy conditions inside a building. Sensor technology has been advancing to the point where Berkeley Lab researchers could use it to study miscellaneous electrical loads at a very fine level of resolution.

"We felt that recent developments in wireless sensor networks would allow us to develop a MELs field study that was relatively low-cost, reliable, and allowed metering all the MELs devices in a home and a representative sample in a commercial building" says Lanzisera. "In the long run, we hope to develop field metering techniques that are more cost-effective and allow more frequent meter readings over longer time periods."

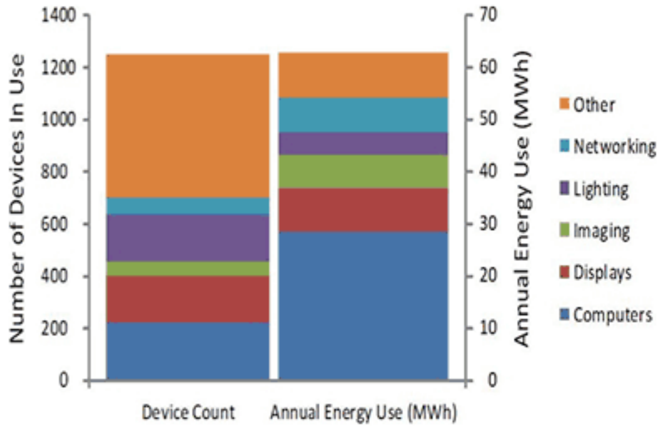


Figure 2. Device count and energy use on the third floor of an office building.

Commercial and Residential Installations

The UC Berkeley team members developed an open wireless sensor network platform called ACme (Alternating Current meter). These meters provide data readings as frequently as every 10 seconds, are accurate to about 0.5% of the reading, and wirelessly transmit the data back to a central database. Because they are based on an open platform, they could be adapted for any project.

The ACme nodes, less than three inches long, are plugged into outlets, and the device to be measured is plugged into the nodes. The ACme nodes form a mesh network that cooperatively sends data packets to a router that communicates power data wirelessly over the Internet to a computer. Each node used in the study cost about $80, and used about 1 Watt of power, so the network added very little to the building's electric load.

The Berkeley Lab-UC Berkeley team measured energy use of MELs in one commercial building, and three homes. They set up a network of ACme nodes in an 89,000-square foot building at Berkeley Lab, an office building typical of older commercial sector structures, housing about 450 occupants, mostly in traditional offices and office cubicles. The team went from office to office, creating a database of every MELs device in the building—about 5,000 total. It took two people about two weeks to complete the inventory, which is shown in Figure 1. The most common devices were computers, computer displays, and other peripherals such as printers and external drives.

Then the team installed 460 ACmes throughout the building on slightly less than 10 percent of the MELs. Their goal was to get a representative sample of MELs from every floor, and every working group, and a wide range of device types.

Three homes formed the residential sample of the their study, two existing homes in Oakland, California, and one new net-zero energy home in Boston. The research team installed 75 to 80 meters per home.

Based on several months of metering, Figure 2 shows some results of energy use and device count for the five most common —computers, displays, imaging, lighting and network devices on one floor of the office building.

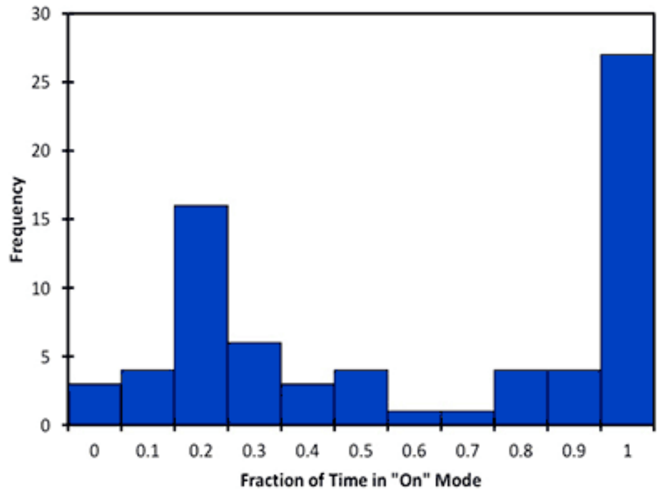


Figure 3. Fraction of Time in the "On" Mode (73 computers)

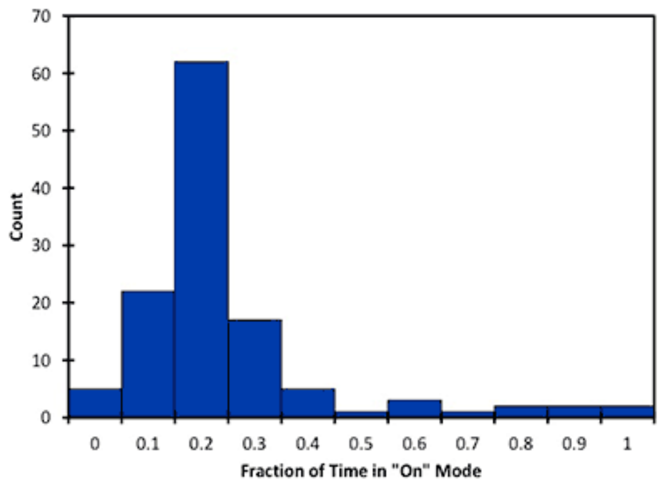


Figure 4. Fraction of Time in the "On" Mode (122 computers)

The tremendous richness of the wireless sensor network makes many kinds of analyses possible. For example, in Figure 3, 73 computers are sorted by the fraction of time they stayed in "on" mode, and Figure 4 shows the same distribution for 122 displays. The conclusion is that most computers are in the "on" mode almost all the time, but a significant number of computers also are powered down much of the time. Meanwhile, displays in this building are rarely left on. Information like this available to a commercial energy manager could motivate simple operational improvements, such as asking the user of computers never turned off to enable their energy-saving low power mode.

The research team is now developing extremely low-cost methods to measure electricity use of electronics. Berkeley Lab, ARM and Power Integrations have demonstrated a method of measuring the power output by a switching power supply (like those used in all electronic devices) that adds only pennies to the device cost. This capability could be added to every electronic device manufactured enabling rich data in buildings.

"We are also working with the efficiency community and device manufacturers on strategies to reduce the energy used by electronics such as computer, audio, and display equipment," says Lanzisera. "This work includes developing advanced controls as well as reducing power use while these devices are operational."

—Allan Chen

For more information:

Steven Lanzisera
(510) 486-4762
SMLanzisera@lbl.gov

Additional information:

This research was conducted by Steven Lanzisera, H.Y. Iris Cheung, Judy Lai, Xiaofan Zhang, and Richard Brown, at Berkeley Lab's Environmental Energy Technologis Division, and Stephen Dawson-Haggerty, Jay Taneja, Jorge Ortz, and David Culler, of the University of California, Berkeley.

S. Lanzisera, S. Dawson-Haggerty, H.Y. Cheung, J. Taneja, D. Culler, R. Brown, "Methods for Detailed Energy Data Collection of Miscellaneous and Electronic Loads in a Commercial Office Building" *Building and Environment*, DOI: 10.1016/j.buildenv.2013.03.025 [http://dx.doi.org/10.1016/j.buildenv.2013.03.025], March 2013.

This research was funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

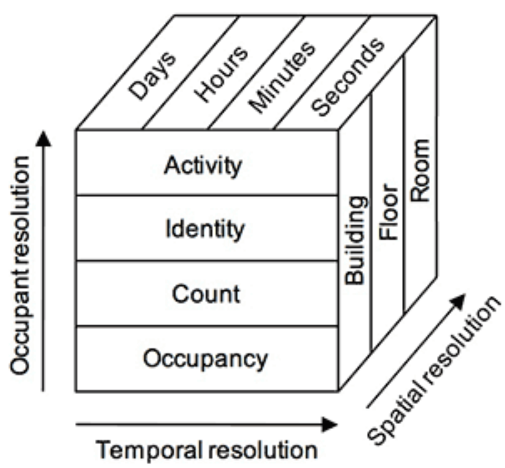
Miscellaneous electric loads [http://plug-in.lbl.gov/]

Using Existing IT to Determine Office Occupancy and Reduce Energy Use

Bruce Nordman

Placed thoughtfully and in sufficient number, building occupancy sensors can provide data sufficient to reduce building energy use, and the potential savings are enormous. However, the time and expense involved in installing and maintaining dedicated occupancy sensors can hinder their widespread use. But what if those savings could be achieved more simply and cheaply, without having to install building sensors, and the data needed to manage a building's energy could be harvested from existing activities, such as keyboard use or the presence of a mobile phone?

Those were the questions that Bruce Nordman and Ben Rosenblum of Lawrence Berkeley National Laboratory's (Berkeley Lab) Environmental Energy Technologies Department (EETD) sought to answer with collaborators Ken Christensen and Ryan Melfi (University of South Florida) and Raul Viera (University of Puerto Rico).



Three fundamental dimensions of "presence" that existing IT infrastructure can determine beyond traditional occupancy's definition, which is a yes/no value.

The project focused on automated solutions that could be used to reduce or switch off electricity to specific equipment when it is not being used. Rather than relying on *explicit* occupancy sensing (such as passive infrared or ultrasonic motion sensors), the team used *implicit* occupancy sensing that drew data from occupants' interactions with the building's existing IT infrastructure. One such strategy is to monitor network addresses in Wi-Fi access points and routers and correlate those addresses with the occupancy of a floor, area, or room of a building. Delivery of services such as HVAC and lighting could then be adjusted accordingly.

The team evaluated the feasibility of this approach at the Engineering Building at the University of South Florida and Berkeley Lab's Building 90, and demonstrated an application of implicit sensing that showed its potential to sense the occupancy of a user workspace and automatically control its plugged-in devices. Three types of approaches were considered: those requiring only a data collection processing point, those that also required additional software, and those that required the data collection processing point and additional software and hardware.

The study showed that no-cost, implicit occupancy sensors were available within the existing buildings and demonstrated the feasibility of implicit occupancy testing. Advantages of using implicit sensors included: avoided cost for sensor installation and maintenance, availability of sensor readings over existing IT networks, and a degree of occupancy resolution (count, identity, and activity) not available from dedicated sensors.

Future work will focus on identifying the level of accuracy needed for optimal control of various equipment and demonstrate directly using the implicit sensing data in building controls.

—Mark Wilson

For more information:

Bruce Nordman
(510) 486-7089
BNordman@lbl.gov

Additional information:

"Using Existing Network Infrastructure to Estimate Building Occupancy and Control Plugged-in Devices in User Workspaces." Christensen, Ken, Ryan Melfi, Bruce Nordman, Ben Rosenblum, and Raul Viera. *International Journal of Communication Networks and Distributed Systems*. January 2014. Vol. 12, No. 1, pp. 4-29.

Bruce Nordman's website [http://nordman.lbl.gov]

LAWRENCE BERKELEY NATIONAL LABORATORY
Environmental Energy Technologies Division
NEWS

Paper Explores Plasmonic Energy Conversion for Photovoltaics and Photocatalytics

While costs for some solar photovoltaics (PV) have dropped sharply over the past few years, the search for PV modules that are both low-cost *and* highly efficient continues. An important focus of that quest is on developing lower-cost, more-efficient methods of attaining electron-hole separation. Plasmonic energy conversion, which generates "hot" (highly energetic) electrons in plasmonic nanostructures through the electromagnetic decay of surface plasmons, is one promising solution. It offers potentially high conversion efficiencies (greater than 22 percent) while keeping fabrication costs low, given the right materials, architectures, and fabrication methods.

Cesar Clavero

César Clavero, an Environmental Energy Technologies Division researcher at Lawrence Berkeley National Laboratory, recently surveyed the research on those topics, to determine the current state of the technology. The resulting paper, "Plasmon-induced hot electron generation in nanoparticle/metal oxide interfaces for photovoltaic and photocatalytic devices," was published in the 30 January 2014 issue of *Nature Photonics*.

The review, which covered fundamentals of hot electron generation, injection, and regeneration in plasmonic nanostructures, found that two key factors promote high conversion efficiencies: fast hot-electron injection before recombination and optimum carrier regeneration. The research also suggests that by combining multiple metals and conducting oxides, the devices will be able to generate electricity from more spectrums of solar radiation, thereby increasing electricity production.

Clavero found that material, size, and shape of the plasmonic nanostructures are the most important design factors affecting the localized surface plasmon resonance (LSPR) electron-generation processes. The literature also suggests that using plasmonic energy conversion could solve the problem of efficiency decreases at higher temperatures, which affects conventional PV cells, because the efficiency with plasmonic structures actually increases with temperature.

While titanium dioxide has been the most-used semiconductor for plasmonic energy conversion, Clavero suggests that the valence bands of zinc oxide, cerium oxide, and silver bromide could also make them efficient electron acceptors. Further studies will need to determine the most efficient semiconductor material.

A Q&A with Cesar Clavero on Plasmonic Energy Conversion

In his review article published in Nature Photonics, Cesar Clavero, a researcher in the Environmental Energy Technologies Division, examines plasmonic energy conversion, a phenomenon that has only been known about for a few years. Clavero examines the speculation that plasmonic energy conversion could be harnessed in a new generation of photovoltaic materials that could be far more efficient at converting solar energy into electricity than what's currently in the marketplace.

What is plasmonic energy conversion?
In plasmonic energy conversion, light from the sun, in the form of photons, are trapped in plasmonic nanostructures on the surface of a specially designed thin film. The photons of light of certain wavelengths form "surface plasmons" within these nanostructures.

Some of the time the light is just re-emitted as photons and radiated back to space. However, at other times, in a non-radiative process, the energy captured in the surface plasmons can be transferred to "hot electrons" and injected into a semiconductor to form an electric current. It has only been under a decade or so that researchers have thought this process could be harnessed into a more efficient way of generating electricity from solar energy.

Various research teams have observed this process taking place in particles of silver or gold deposited in tube nanostructures of titanium dioxide, however the use of other materials such as conducting oxides would extend the range of applicability of this technology.

What's the difference between this process and how an electric current is generated in conventional photovoltaic panels on the market today?
In a conventional PV panel, photons in the sunlight that have high enough energy are absorbed by electrons in the semiconductor film that forms the photovoltaic panel. The process forms an "electron-hole pair." The electrons become mobile, resulting in the electric current, and the positively charged "holes" in the lattice of the semiconductor material maintain the overall charge balance of the material. This process has a theoretical maximum energy conversion efficiency that cannot be exceeded by simple improvements to material.

Why is plasmonic energy conversion promising as a method of achieving higher efficiency of energy capture than in conventional semiconductor-based PV materials?
The physics of the plasmonic energy conversion process is fundamentally different from that of the photoelectric effect that generates current in the conventional PV panels. In plasmonic energy conversion, the process takes place on nanostructures, at the nanoscale. A surface plasmon-based photovoltaic material would be much thinner—instead of micrometers thick, it would be nanometers thick. This opens the possibility of PV panels with coatings that are much thinner and therefore considerably less expensive to manufacture than today's panels, yet much more efficient at trapping energy.

Also, in the review article in *Nature Photonics*, I suggest that a wide range of metal oxides could use plasmonic energy conversion to capture energy from a broader range of wavelengths of the solar spectrum than are currently captured by conventional PV devices. Capturing energy across the whole solar spectrum—visible and infrared light helps increase the efficiency of these devices.

What are the barriers to exploiting plasmonic energy conversion in solar photovoltaic devices?
The field is in its infancy and there is much we don't know about what materials are best at generating hot electrons from the solar spectrum, how to build and optimize nanostructures for maximum efficiency, and so on. But there are great opportunities for Berkeley Lab to explore a groundbreaking new field that could lead to the fabrication of much more efficient, cheaper solar PV devices. This research direction has the potential to cause a great leap in the use of solar photovoltaic technology to generate electricity.

What do you think are the next steps to advance this field?
A great window of opportunity has opened in the field of plasmonic energy conversion. The use of new plasmonic materials such as semiconductors and conducting oxides, combined with new architectures such as multijunction plasmonic solar cells, will allow us to further push the energy conversion limits while keeping low fabrication costs. Also, fundamental studies shining light onto the hot-electron generation, injection and regeneration processes will be key to advance this field.

—Mark Wilson

For more information:

Cesar Clavero
(510) 486-5416
CClavero@lbl.gov

Additional information:

Nature Photonics journal article [http://www.nature.com/nphoton/journal/v8/n2/full/nphoton.2013.238.html]

This work was supported by the Department of Energy's Office of Energy Efficiency and Renewable Energy, Office of Building Technology.

Research Highlights

EETD Researcher Named a 2014 Schmidt-MacArthur Fellow

EETD's Hanna Breunig has been named one of 16 Schmidt-MacArthur Fellows in the program's class of 2014.

Hanna Breunig

Breunig is a graduate student researcher in the Sustainable Energy Systems Group's emerging technology analysis group, Environmental Energy Technologies Division, and a PhD candidate in the Department of Civil and Environmental Engineering at the University of California, Berkeley. She is one of 16 Schmidt-MacArthur fellows in the class of 2014.

The Schmidt-MacArthur Fellowship is an international postgraduate fellowship on the circular economy for design, engineering and business students. The Fellowship programme, a joint initiative between the Ellen MacArthur Foundation [http://www.ellenmacarthurfoundation.org/] in the U.K. and the Schmidt Family Foundation [http://www.11thhourproject.org/] in the U.S., offers an innovation platform for postgraduate students and academics from leading international design, engineering & business schools to redesign the economy.

As mentor to Breunig, Sustainable Energy Systems Group Leader Thomas McKone was also honored by the Schmidt-MacArthur selection committee.

For more information:

Hanna Breunig

(585) 217-7512

HannaMSmith@lbl.gov

Schmidt-MacArthur Fellows announcement [http://www.ellenmacarthurfoundation.org/education/higher/news/schmidt-macarthur-welcomes-16-new-students-for-2014]

Breunig web page [http://gadgillab.berkeley.edu/people/hanna-breunig/]

EETD Division Director Ashok Gadgil Named to 2014 Induction Class of National Inventors Hall of Fame

Ashok Gadgil, EETD Division Director

The National Inventors Hall of Fame [http://invent.org/] (NIHF), in partnership with the U.S. Department of Commerce's United States Patent and Trademark Office [http://www.uspto.gov/] (USPTO) has named EETD Division Director Ashok Gadgil a member of its 2014 Class of Inductees. The NIHF Inductee list includes inventors who have made extraordinary contributions to their respective fields, and in many cases, changed the world forever.

Gadgil was cited for "Innovative solutions for providing clean water in the world's developing nations," — the citation refers to the UV Waterworks device, and inexpensive device to disinfect drinking water.

For more information:

Ashok Gadgil in the National Inventors Hall of Fame [http://invent.org/inductees/gadgil-ashok/]

UV Waterworks [http://eetd.lbl.gov/l2m2/waterworks.html]

WaterHealth International [http://www.waterhealth.com/]

EETD's Adam Weber Named A Winner of the Presidential Early Career Award by President Obama

Adam Weber

The White House has announced that Adam Weber has won a Presidential Early Career Award. Weber is a staff scientist at the Environmental Energy Technologies Division of Lawrence Berkeley National Laboratory (Berkeley Lab). His current research involves understanding and optimizing fuel-cell performance and lifetime; understanding flow batteries for grid-scale energy storage; and analysis of solar-fuel generators.

Weber holds B.S. and M.S. degrees from Tufts University, and a Ph.D. from the University of California, Berkeley in chemical engineering. He has authored more than 40 peer-reviewed articles on fuel cells, flow batteries, and related electrochemical devices, developed many widely used models for fuel cells and their components, and has been invited to present his work at various international and national meetings including the Gordon Research Conference on Fuel Cells, the Special Invitation Session at FC Expo 2007, and 4 keynote lectures at national society meetings.

He has also been the recipient of a number of prestigious awards including a Fulbright scholarship to Australia, the 2008 Oronzio and Niccolò De Nora Foundation Prize on Applied Electrochemistry of the International Society of Electrochemistry, and the 2012 Supramaniam Srinivasan Young Investigator Award of the Energy Technology Division of the Electrochemical Society.

According to the White House press release, the Presidential Early Career Awards "embody the high priority the Obama Administration places on producing outstanding scientists and engineers to advance the Nation's goals, tackle grand challenges, and contribute to the American economy…The awards, established by President Clinton in 1996, are coordinated by the Office of Science and Technology Policy within the Executive Office of the President. Awardees are selected for their pursuit of innovative research at the frontiers of science and technology and their commitment to community service as demonstrated through scientific leadership, public education, or community outreach."

For more information:

Adam Weber

(510) 486-6308

AZWeber@lbl.gov

White House Press Release [http://www.whitehouse.gov/the-press-office/2013/12/23/president-obama-honors-outstanding-early-career-scientists]

10 Questions for a Scientist: Dr. Adam Weber [http://energy.gov/eere/articles/10-questions-scientist-dr-adam-weber-lawrence-berkeley-national-laboratory]

Using Direct-DC Power Distribution in U.S. Residential Buildings Can Save Energy

An increasing fraction of the most efficient appliances on the market operate on direct current (DC) internally, making it possible to use DC from renewable energy systems directly and avoid the losses inherent in converting power to alternating current (AC) and back, as is current practice. Products [http://www.emergealliance.org/Products/RegisteredProducts.aspx] are also emerging on the commercial market that take advantage of that possibility.

Lawrence Berkeley National Laboratory researchers Vagelis Vossos, Karina Garbesi, and Hongxia Shen investigated the potential savings of direct-DC power distribution in net-metered residences with on-site photovoltaics (PV) by modeling the net power draw of the 'direct-DC house' with respect to today's typical net-metered AC-house configuration. Both houses were assumed to have identical DC-internal loads based on an analysis of 32 electricity end-uses, all of which were found to be DC-compatible.

Model comparisons were run for 14 representative cities across the United States, using hourly, simulated PV-system output and residential loads. The modeling tested the effects of climate, load shifting, and battery storage, as well as considered partial load conditions. A sensitivity analysis determined how future changes in power system component efficiencies might affect potential energy savings.

Results showed that net-metered PV residences without storage could save 5 percent of their total electricity load by using DC-internal appliances, and those with battery storage could save 14 percent of their total load. The residence without battery storage would achieve only a modest savings because the time of peak PV production (midday) does not coincide with the peak residential load (late afternoon/evening). However, residential PV systems incorporating battery storage could achieve much higher savings because the system can both save and use the generated power in DC form.

The project also found that direct-DC energy savings are sensitive to power system and appliance conversion efficiencies, but that they are not significantly influenced by climate.

V. Vossos, K. Garbesi, H. Shen. "Energy Savings from Direct-DC in U.S. Residential Buildings. [http://dx.doi.org/10.1016/j.enbuild.2013.09.009]" *Energy and Buildings*. 68 (2014),pp. 223-231.

For more information:

Evangelos Vossos

(510) 495-2521

EVossos@lbl.gov

Berkeley Lab Signs Memorandum of Understanding with Greenhouse Gas Inventory and Research Center of Korea

Berkeley Lab MOU signing ceremony with Greenhouse Gas Inventory and Research Center of Korea (GIR). Pictured are Youngmin Kim (right), GIR Director of Planning and Coordination and Paul Alivisatos, Berkeley Lab Director.

Representatives of Lawrence Berkeley National Laboratory (Berkeley Lab) and the Greenhouse Gas Inventory and Research Center of Korea (GIR) have signed a Memorandum of Understanding to explore potential areas of collaboration. For Berkeley Lab, the MOU is centered in its Environmental Energy Technologies Division (EETD). The areas of potential cooperation include energy sector planning, policy analysis, energy modeling.

GIR and Berkeley Lab will explore expanding their existing collaborations in energy sector assessment for energy efficiency, renewable energy, and green technology deployment, policy analysis, and energy modeling for greenhouse gas emissions abatement. The two organizations also have a mutual interest in studying energy consumption behavior and technology adoption in developing countries.

Building America's Housing Innovation Award

The U.S. Department of Energy recognized Lawrence Berkeley National Laboratory in the area of advanced technologies and practices for research on high-efficiency furnace blowers. The project team consisted of Iain Walker, Darryl Dickerhoff and Jim Lutz of the Environmental Energy Technologies Division. Their work is credited with leading to the incorporation of energy-efficient blowers in U.S. energy efficiency programs and building codes, and the creation of a Canadian standard for rating air system blowers.

Building America's Top Innovations Advance High Performance Homes [http://energy.gov/eere/articles/energy-department-announces-winners-housing-innovation-awards]

The Darfur Stoves Project Wins a 2013 Tech Award

Darfur stove

The Darfur Stoves Project, now managed by the non-profit organization Potential Energy [http://www.potentialenergy.org/], originated as an effort at Lawrence Berkeley National Laboratory to develop fuel-efficient stoves. These stoves reduced the need for women in the Darfur camps to forage for wood, where they were exposed to violence. Learn more at the link below. The project's efforts are now expanding to other regions.

The Tech Awards are presented by the Tech Museum of Innovation, Santa Clara California. These awards honor laureates from around the world for their efforts to use technology to benefit humanity. Tech Awards laureates are individuals, non-profit organizations and for-profit companies. The technology they use is either a new invention or an innovative use of an existing technology.

MAnufacturing STructure and Energy Research Tool (MASTER)

The China Energy Group of Lawrence Berkeley National Laboratory has released the MAnufacturing STructure and Energy Research (MASTER) tool. The MASTER tool is designed to help users understand how different factors (production growth of industry subsectors, industry structural change, and energy intensity change of industry subsectors) influence overall industrial energy use trends over time. Policy makers often seek such values in order to make more informed decisions related to energy and industrial policies. This tool helps to quantitatively compare the effect of structural change (i.e. the change in share of value added of manufacturing subsectors) in the past and in the future, so that if needed, policy makers can adjust their policies to help realize China's or other countries' goals to move toward less energy-intensive, higher value added industries. Different scenarios can be developed using this tool to show the structural change achieved through different paths and to understand the consequences of supporting or limiting the growth of certain manufacturing subsectors from the point of view of energy use and structural change.

Based on the energy use and value added data input by the user, the MASTER tool conducts the decomposition analysis for different time periods in the past or in the future chosen by the user. The decomposition analysis results can be viewed by industrial subsector. The tool also presents energy use, value added, and energy intensity trends in graphical form.

The MASTER tool can be used by the local and national government as well as academia and other organizations to analyze the past and future energy trends of industry in a given region or country. It can help to quantify industrial structural change during the study period and how it affects the industrial energy use.

The tool is available in both English and Chinese language [http://china.lbl.gov/tools-guidebooks/master].

For more information:

Ali Hasanbeigi

(510) 495-2479

AHasanbeigi@lbl.gov

Sources and Credits

Sources

Energy Efficiency & Renewable Energy's Energy Savers

These web pages [http://energy.gov/energysaver/energy-saver] provide information about energy efficiency and renewable energy for your home or workplace.

DOE's Energy Information Administration (EIA)

EIA [http://www.eia.gov/] offers official energy statistics from the U.S. Government in formats of your choice, by geography, by fuel, by sector, or by price; or by specific subject areas like process, environment, forecasts, or analysis.

DOE's Fuel Economy Guide

This website [http://www.fueleconomy.gov/] is an aid to consumers considering the purchase of a new vehicle.

DOE's Office of Energy Efficiency & Renewable Energy (EERE)

EERE's [http://www.eere.energy.gov/] mission is to pursue a better energy future where energy is clean, abundant, reliable, and affordable; strengthening energy security and enhancing energy choices for all Americans while protecting the environment.

U.S. DOE, Office of Science [http://science.energy.gov/]

U.S. EPA, ENERGY STAR Program [http://www.energystar.gov/]

California Energy Commission [http://energy.ca.gov/]

Credits

Editor
Allan Chen

Contributing Editor
Mark Wilson

Art Director
Anthony Ma

Web Design
Sondra Jarvis

Circulation
Joanne Lambert

Division Director
Ashok Gadgil

Building Technology and Urban Systems
Mary Ann Piette

Communications Office
Allan Chen

Energy Analysis and Environmental Impacts
Charles Goldman

Energy Storage and Distributed Resources
Venkat Srinivasan

Environmental Energy Technologies Division

The mission of the Environmental Energy Technologies Division is to perform research and development leading to better energy technologies and the reduction of adverse energy-related environmental impacts.

Ordering Information
EETD News
Lawrence Berkeley National Laboratory
University of California

Tel: (510) 486-4835
Fax: (510) 486-5394
Email: JMLambert@lbl.gov

LBNL/PUB-821 Vol. 12, No. 3 [http://eetd.lbl.gov/newsletter/nl46/], Winter 2014

The current and all past issues of *EETD News* [http://eetd.lbl.gov/newsletter/] are available on the World Wide Web.

Sign up for an "e-mail" subscription and get on our Electronic Notification list [http://eetd.lbl.gov/newsletter/sub/newsletter_signup.php]. You will receive an e-mail when a new issue is available.

This work was supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Ernest Orlando Lawrence Berkeley National Laboratory is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy. The oldest of the nine national laboratories, Berkeley Lab is located in the hills above the campus of the University of California, Berkeley.

With more than 4,000 employees, Berkeley Lab's total annual budget of nearly $600 million supports a wide range of unclassified research activities in the biological, physical, computational, materials, chemical, energy, and environmental sciences. The Laboratory's role is to serve the nation and its scientific, educational, and business communities through research performed in its unique facilities, to train future scientists and engineers, and to create productive ties to industry. As a testimony to its success, Berkeley Lab has had 11 Nobel laureates. EETD is one of 14 scientific divisions at Berkeley Lab, with a staff of 400 and a budget of $40 million.
