LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

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A new research facility is taking shape at Lawrence Berkeley National Laboratory—the Facility for Low-Energy eXperiments in Buildings. In this issue we feature an article previewing the FLEXLab's capabilities, especially its two indoor testbeds: for lighting and plug loads, and for virtual design. A second article describes the exciting capabilities of the lighting and plug load testbed in more detail. The lighting and plug load testbed is the most densely instrumented and minutely controlled building space anywhere in the United States—a stretch of building so finely regulated that every power outlet is individually monitored and can be turned on or off.

You'll also find an update on recent progress of the OpenADR communications protocol for automated demand response, a report of our work on energy efficiency projects for the Department of Defense, and a summary the most recent Tracking the Sun report, which documents the continuing fall in the price of PV modules.

EETD researcher Vi Rapp contributes an article about her work on assessing safety diagnostics for atmospherically vented combustion appliances. We also report on a study of the energy use of plug loads on the UC Berkeley campus and describe a recent study of indoor air quality in California childcare facilities.

If you are new to *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].

Fall Newsletter: Vol. 11, No. 2 [http://eetd.lbl.gov/newsletter/nl41/]
Environmental Energy Technologies Division News [http://eetd.lbl.gov/newsletter/]

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Berkeley Lab Opens First Phase of FLEXLAB, a New Laboratory for Energy-Efficient Buildings

Lawrence Berkeley National Laboratory (Berkeley Lab) recently opened the first two testbeds of FLEXLAB, the Facility for Low Energy eXperiments in Buildings. FLEXLAB is a set of testbeds for studying and demonstrating energy-efficient building technologies. Constructed within an existing building, they will allow Berkeley Lab researchers and their partners to study and demonstrate energy-efficient lighting systems and to collaborate in the design of the next generation of energy-efficient, automatically monitored and controlled buildings.

The Lighting and Plug Load Test Bed.

The interior testbeds are the Lighting and Plug Load Testbed and the Virtual Design Testbed. Each is reconfigurable, and can be divided into zones and outfitted as offices. This fall, researchers in Berkeley Lab's Environmental Energy Technologies Division (EETD) held a series of workshops to acquaint potential users with FLEXLAB, which will eventually include additional testbeds in a new outdoor facility. Participants included a broad cross-section of industry, utilities, the U.S. Department of Energy, state and local governments, manufacturers, and the architectural and engineering design community.

"These new testbeds will provide the building industry and the architecture and engineering community with a heavily instrumented facility for developing and validating the performance of new energy-efficient technologies," said Cindy Regnier, the Technical Manager of the FLEXLAB facility. "They will also help them develop integrated building system solutions for reducing energy and resource use and maximizing human comfort in buildings."

The Interior Testbeds Are Ready for Use

The Lighting and Plug Loads [http://eetd.lbl.gov/news/article/15326/testing-efficient-lighting-and-building-control-solutions-at-berkeley-lab-the-fir] Testbed is a densely instrumented living laboratory that can be used to test real-life office environments, allowing for a wide variety of control strategies, ranging from fully automated control to manual control by occupants.

Users can monitor every change in the power use and lighting conditions of the testbed, continuously and in real-time. Every duplex power outlet is individually monitored and can be turned on or off by occupants or be programmed for other controls, such as those that respond to occupancy.

In the Virtual Design Testbed, users will design and develop advanced energy-efficient buildings in a collaborative setting. Participants present in the room, as well as those joining meetings remotely, will put up and modify ideas, share data, and develop designs collaboratively, using building design and simulation tools such as the recently released Simergy tool, which provides a graphical user interface to EnergyPlus. This testbed will be used to help develop interoperable software tools used throughout the building lifecycle from building design through operations.

New Exterior Testbed Construction Is Next

Outside this building, construction teams have begun building four testbeds. When complete, EETD researchers and their public- and private-sector research partners will be able to swap out building components and systems, and then measure, analyze, and improve their performance under real conditions (see rendering). FLEXLAB's exterior facility will be completed late in 2013. The interior and exterior testbeds are comprised of 9,000 square feet of floor space, and are funded by the American Reinvestment and Recovery Act (ARRA) through the U.S. Department of Energy.

In the new exterior facility, each testbed will be reconfigurable—depending on the research plan, users will be able replace windows, walls, access floor, lighting, HVAC systems, and other elements with prototypes for testing. The interior spaces will be reconfigurable—they can be divided into zones and outfitted as offices.

One testbed can be rotated to different orientations with respect to the sun, to adjust the structure's solar exposure as desired. It can reset its position every 60 seconds to align with solar orientation to measure how sun position impacts energy use and interior conditions.

Another double-height testbed is designed to test technologies designed for two-story structures, with applications that include big-box retail environments. These modules will also test technologies such as skylights and clerestories.

Diverse instrumentation in the testbeds will allow users to remotely monitor and control a wide range of variables, from energy use to exterior weather to interior comfort conditions such as temperature, pressure, and humidity. Occupancy sensors, air-flow and room pressure measurements, lighting and glare, and thermal conditions are among the factors that the facility's instrumentation can monitor.

"To develop the extremely energy-efficient, comfort-maximizing buildings of the future," says Regnier, "building designers and developers are moving toward integrated systems, real-time monitoring of building conditions, and advanced control algorithms that optimize both energy use and interior conditions for maximum comfort."

"In this new facility," she continues, "we will have the fine level of data collection and analysis we need, along with the ability to adjust and configure every aspect of the test spaces to develop, field-test, and prove out new technologies, as well as to solve fundamental problems in design and operations that we need to move the building industry to a new level of consistent energy savings."

Total ARRA funding is 15.7 million dollars. Stantec Architecture is the architect of record, with mechanical and electrical engineering provided by Integral Group and structural engineering by Tipping Mar.

—Allan Chen

Additional information:

FLEXLAB website [http://flexlab.lbl.gov/]

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Testing Efficient Lighting and Building Control Solutions at Berkeley Lab: The First FLEXLAB Module Takes Shape

As clouds pass in front of the sun, incoming daylight is reduced in the interior of a section of the fourth floor of an office building at Lawrence Berkeley National Laboratory (Berkeley Lab). In this new lighting and plug load testbed, light sensors read the change in light levels, and energy-efficient ceiling fixtures gradually increase their light output to compensate.

Sensors on every light fixture report power consumption data in real time for recording, while other sensors measure ambient and desk-height light levels. The clouds drift away, incoming sunlight intensity increases, and the louvers of motorized blinds automatically realign themselves to maintain a comfortable, glare-free light level in the fourth floor's interior while the automated control system dims the overhead lights.

Sensors measure every significant variable and send data continuously for recording and later analysis by building scientists in the Environmental Energy Technologies Division (EETD). Office workers in the space are aware of the dynamics taking place around them but pleased the conditions are always maintained in the comfort zone.

Artist rendering of FLEXLAB's outside modules.

This is a time of tremendous creativity and innovation in the buildings industry. The industry is working to meet the economic and social goals of designing and constructing buildings that use far less energy than today's conventional buildings. Manufacturers of lighting, HVAC equipment, building envelope products, and energy management systems are all developing new technologies. Their work promises greater energy efficiency, more comfortable interiors, and more knowledge about (and control over) building energy use and the interior environment than ever.

But the buildings industry will not adopt new technologies and systems without proof that they actually save energy under real conditions and make building interiors more comfortable and easier to control. New commercial buildings cost tens to hundreds of millions of dollars and have service lives lasting for decades. Owners and builders won't take a chance and install unproven technologies whose performance may fall short.

Now under construction at Berkeley Lab is a unique research and demonstration facility that will help industry develop and fine-tune new building technologies. It will also generate accurate, unbiased performance data. The Facility for Low Energy eXperiments in Buildings (FLEXLAB) will consist of four new outdoor test modules, as well as several testbeds within an existing building. It will be operated by the EETD, which is seeking industry partners for cooperative research. Read more about it here [http://flexlab.lbl.gov/].

In FLEXLAB, Berkeley Lab and its partners will conduct research and product development on single components or whole-building systems integration. They'll be able to replace any building system such as exterior building envelope, windows and shading systems, lights, HVAC, energy control systems, and roofs and skylights, as well as interior components such as furniture, partitions, and raised floors.

While construction of the new outdoor facilities gets under way, another part of FLEXLAB has completed construction: the lighting and plug load testbed, and a virtual design testbed.

Unmatched Control of Lighting and Plug Loads

The lighting and plug load testbed is the most densely instrumented and minutely controlled building space anywhere in the United States—a stretch of building so finely regulated that every power outlet is individually monitored and can be turned on or off; every light fixture in the office cubicles is individually metered and controlled. "This is more advanced than any other facility in the buildings industry," says Steven Lanzisera, one of the researchers on the testbed's design team.

This 4,000 square foot floor area has room for 15 cubicles plus a row of perimeter offices along both sides of the building (eight in all). Francis Rubinstein, who helped design the testbed's lighting system and controls, says "every single light fixture in the testbed will be individually monitored. We can control the lights in the four rows of overhead fixtures in eight-foot segments. We'll also be able to measure the input power along each eight-foot segment."

"The ability to control and measure each fixture individually is unique to this testbed," says Rubinstein. "You don't get this level of control in any other test facility."

Rubinstein also adds that occupancy sensors control the energy-efficient LED task lighting fixtures in each cubicle. The occupancy sensors can turn them off when the occupant leaves. Fifteen ceiling-mounted photosensors can measure the illumination distribution throughout the study space. Additional photocells are installed at the tops of partitions separating the cubicles, as well as at the desk surface as required to adequately sample daylight conditions as they vary across the day.

Researchers will test different control algorithms for dimming electric lighting up or down to balance the daylight in the space, as well as for controlling automated fenestration systems.

"A lot of flexibility is built in to the algorithm to allow for individual control," says Rubinstein, "with the end result that we have a densely instrumented living laboratory that we can use to test real-life situations, mixing a variety of automated control strategies with manual control by occupants."

Control is in the Software

"A unique feature of the testbed," says Lanzisera, "is that all control is done in the software of the control algorithm—outside of the hardware."

"Traditionally," he continues, "controls are internal to the hardware, but here, all the control algorithms are on the outside, and the sensor data is logged continuously, and viewable using Labview software. If someone has a control methodology they want to test, it's easy to implement in the software."

This arrangement lets teams of researchers study how individual decisions are made about light levels and equipment energy use, and what sensory input went into the decision-making process. Their observations will lead to better algorithms for controlling system-wide energy use.

Protocols for Maximum Performance

"We envision a series of experiments in cooperation with private-sector partners to study the performance of new lighting controls and plug load technologies involving lighting fixtures, power supplies, plug strips, and software technologies for shedding load [reducing power consumption during periods of heavy demand]," says Rubinstein. "We hope to conduct experiments that will allow us to test several different technologies at the same time, and develop control strategies to maximize the energy savings and maintain comfortable conditions within the space."

Another purpose of the testbed is to study how design intent behind use of technologies matches up to actual performance, and to work out control strategies that allow building operators to get maximum performance. "We'll be documenting system installations, the commissioning procedures we used to ensure they meet their design intent, and how to operate the systems for highest performance," says Rubinstein.

Discussions Under Way Now with Potential Partners

While the outdoor testbeds are designed for use as unoccupied spaces with simulated occupancy, the lighting and plug load test lab will be fully occupied by EETD staff. After construction on the lighting and plug loads testbed was complete, the testbed was commissioned, and the facility was reoccupied by staff in October. The first team of industry partners is currently planning a test program to be implemented starting in late 2012.

FLEXLAB staff are now in discussions with other potential partners to develop a program of cooperative research in the lighting and plug loads testbed, as well as for the rest of FLEXLAB, whose centerpiece is the four-module facility, which will be finished in the winter of 2013.

Berkeley Lab invites interested partners to contact FLEXLAB staff for more information about how to perform research with us in the new facility and demonstrate new technologies and systems that will help achieve aggressive new performance goals for America's building stock.

—Allan Chen

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Facility for Low Energy eXperiments in Buildings (FLEXLAB) website [http://flexlab.lbl.gov/].

FLEXLAB [PDF [http://flexlab.lbl.gov/pdf/flexlab-brochure.pdf]].

The FLEXLAB facility is funded by the U.S. Department of Energy.

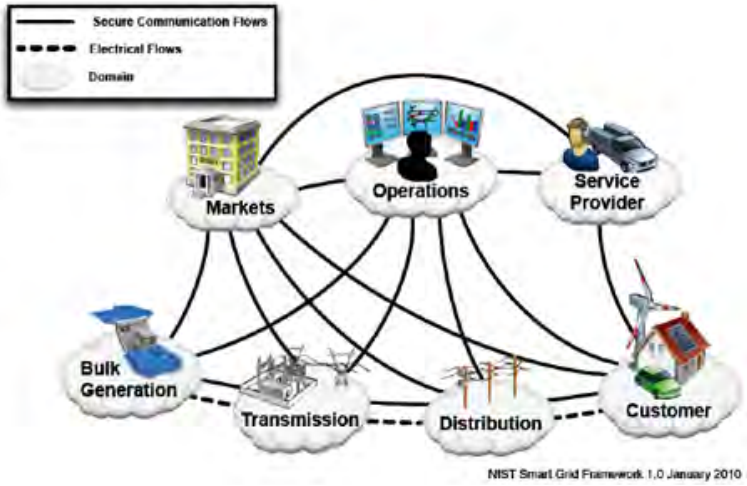
LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

OpenADR Continues to Move the Smart Grid Forward

Open Automated Demand Response (OpenADR)—the standard for open automation of building electricity demand response and price communications—has gained considerable attention since it emerged from Lawrence Berkeley National Laboratory's (Berkeley Lab's) Demand Response Research Center in 2008. This non-proprietary DR interface facilitates open, standardized communication that enables power providers and managers to securely communicate wholesale and retail price and reliability, as well as DR program information, with customers using existing electronic communications. Developed as an effective means for DR service providers to maintain grid reliability and for customers to benefit (and profit from) demand reduction, OpenADR is now becoming an integral component of the U.S. and international Smart Grid.



OpenADR's Role in Smart Grid Energy Management. By enabling secure, data-rich, real-time communications among the network of electricity suppliers, managers, and users, OpenADR facilitates efficient, potentially lower-cost electricity transactions.

OpenADR 1.0 was developed as a non-proprietary open communication specification by Berkeley Lab researchers and industrial partners for U.S. markets. In 2009, they donated it to the Organization for the Advancement of Structured Information Standards (OASIS), where it became the basis for the formal international Energy Interoperation 1.0 standard. In 2010, OpenADR 1.0 became a U.S. Smart Grid standard supported by the U.S. Department of Energy (DOE) and the National Institute of Standards and Technology (NIST). Today it supports more than 250 megawatts of automated DR in California alone, and cleantech market intelligence firm Pike Research predicts that it will be used in nearly 170,000 sites by 2018.

As its presence in the world of clean technology and supply and demand integration increases, OpenADR developments are moving apace. The OpenADR Alliance, a member-represented non-profit organization, is working to simplify DR adoption; the formal OpenADR 2.0a Profile Specification, based on the Energy Interoperation 1.0 standard, was recently released; various companies have developed and are commercializing products based on OpenADR 2.0a; and research and development continues move OpenADR standards and products into the global marketplace.

Here is a summary of some of the latest developments with OpenADR 2.0.

OpenADR Alliance

Founded in 2010 by Berkeley Lab, Pacific Gas and Electric Company, Southern California Edison, and Honeywell, the OpenADR Alliance is a member-represented nonprofit corporation created to foster the development, adoption, and compliance of the OpenADR standard through collaboration, education, training, testing, and certification. In 2011, the Alliance developed technical and marketing committees and a conformance and testing program to help OpenADR become an accepted standard and to facilitate its wider adoption. It also formed working groups and committees to facilitate the development of, and transition to, the formal industry standard, OpenADR 2.0.

Girish Ghatikar

Girish Ghatikar, a Berkeley Lab researcher and Vice-Chairman of the OpenADR Alliance leading the project describes the work's significance: "Bringing the lab technologies and science to the market and engaging stakeholders closely in the process are both integral to OpenADR research and development. The Alliance has helped to make OpenADR a success story of the U.S. Smart Grid interoperability standards, and is now helping it gain significant momentum within the international community."

Open to all interested stakeholders, the OpenADR Alliance is now an industry member-sponsored organization. With more than 75 members that range from equipment and software vendors to electric service providers and research institutions across the world, the Alliance continues to work with other entities to develop and advance the standard. Part of this work is the creation of a series of OpenADR 2.0 profiles (a, b, and c) that address increasing levels of technological complexity and device and market requirements. OpenADR 2.0a was released in August 2012, and 2.0b is currently in development.

The OpenADR 2.0a Profile Specification

The OpenADR 2.0a profile specification addresses cyber-security requirements and facilitates global interoperability standards. It enables commercial, industrial, and residential customers to automate their response to high energy prices and grid instability through demand response; helping them better manage their energy costs during peak demand periods, while helping utilities maintain grid reliability during those high points of electricity demand.

To accomplish this, OpenADR 2.0a offers secure, two-way communication between DR servers and automated DR clients and continuously communicates DR and dynamic price signals to customers. It is the only data model that bridges communications between utility and customer-owned control systems. OpenADR 2.0a supports activities, such as lowering temperatures or switching off lights to reduce electricity demand, which are applicable for most of the current DR markets; future profiles will support more complex actions to support wholesale DR markets and closer links to electricity generation.

OpenADR 2.0a Products

The following OpenADR 2.0a-certified devices were released in September 2012, and more vendors are interested in certifying their products:

The **EnerNOC Site Server** is a communications gateway or a secure client that interfaces with a building's control equipment to collect aggregated stream end-user data to EnerNOC's Network Operations Center, supporting a customer's ability to manage its energy in real time.

Akuacom, a Honeywell company, released its **Demand Response Automation Server** (DRAS), which securely broadcasts price, reliability, and other DR signals. The server passed both the required and optional OpenADR 2.0a functional tests. Akuacom currently provides commercial-grade DRAS for California utilities' automated DR programs, which are based on the OpenADR 1.0 specification.

The **Energy Interop Server & System** (EISS™), from **IPKeys,** Inc., is a server that enables energy providers to securely exchange two-way market signals with customers. Another IPKeys product, **EISSBox,** is a client that interfaces with a building's equipment to automatically receive and respond to DR and price event signals. IPKeys is unique in providing both server and client products. These products were pilot tested in spring 2012 by PJM (the eastern U.S. independent transmission system and wholesale market operator) and six commercial participants. The facilities reduced their loads via different means, but all achieved their load-reduction goals successfully. See "OpenADR Advances [http://bookstore.ashrae.biz/journal/download.php?file=ASHRAE-D-AJNov12-BS16-BS19_BACnet_Holmberg.pdf]" for more about the pilot test.

Universal Devices ISY99i Z Series is an easy-to-configure, low-cost, standalone energy management, monitoring, and automation client that support different protocols and devices such as ZigBee, INSTEON, A10, and X10 products.

The logo for OpenADR 2.0a-certified products.

The products were all pre-tested using a test tool developed by QualityLogic and certified by a test lab, Intertek, helping increase the confidence of electricity service providers, aggregators, and customers in purchasing and implementing this equipment to automatically manage energy use. In addition, pilot tests are in the works, both in the United States and around the world.

OpenADR International Adoption

The use of OpenADR outside of the United States is beginning to gain inroads in Canada, the United Kingdom, Ireland, South Korea, China, Hong Kong, Australia, India, and Japan. For example, in China, as part of the U.S.-China Energy Cooperation Program, Honeywell has teamed with the Tianjin Economic-Technological Development Area to conduct a pilot study with commercial and industrial facilities in the area. China Light & Power in Hong Kong is conducting a similar pilot study. In addition, projects in South Korea and Japan are evaluating the feasibility of DR automation to address issues with increasing demand and integration with renewables. Ireland, Spain, Japan, Taiwan, India, and Turkey have also expressed interest in discussing potential OpenADR applications in their Smart Grid plans.

"OpenADR 2.0 is now being considered for standardization by the International Electrotechnical Commission (IEC – an international standards development organization). If successful, this process will likely lead to international standardization and thus ease its adoption across the global smart grid markets and use of OpenADR technologies developed in the U.S and elsewhere."

OpenADR users are being drawn to the specification because of its openness, flexibility, and low cost of implementation. In fact, it's increasingly the most common global standard used for DR automation. Vendors can produce innovative products without being hampered by intellectual property or patent concerns, and businesses and customers don't have to commit to a single vendor to meet all of their equipment needs. As the standard gains wider acceptance, the prevalence of more vendors and products is likely to lead to lower equipment costs and provide additional value streams within different DR markets.

Future Development and Support

Even so, researchers, standards and industry groups are continuing to collaborate with one another, to broaden the adoption of and applications for OpenADR through testing, and by ensuring that the standard is scalable, cost-effective, and accessible to all customer levels. OpenADR 2.0 pilot tests will be watched by users and developers, to monitor performance capabilities and assess market needs.

Work is ongoing on the OpenADR 2.0b and OpenADR 2.0c profile specifications. OpenADR 2.0b, expected to be released by the end of 2012, is designed for high-end embedded devices and features a flexible reporting mechanism for data reports and wholesale DR markets. OpenADR 2.0c would address sophisticated controls and high-end computer systems, and support all services and markets, including energy transactions (two-way buying and selling of electricity) and aggregators; however, the North American Electric Reliability Council has suggested that the OpenADR 2.0b already meets the need of wholesale DR markets. The development of 2.0c profile will be based on research progress and market need.

"The OpenADR Alliance will continue to assess market and technical needs and collaborate with others to unlock OpenADR's potential," says Ghatikar. "We've only begun to see the benefits that the use of this open standard and innovations will bring to the Smart Grid."

—Mark Wilson

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Demand Response Research Center website [http://drrc.lbl.gov/].

OpenADR Alliance website [http://www.openadr.org/].

NIST Smart Grid Collaboration Wiki Smart Grid Interoperability Panel website [http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/OpenADR].

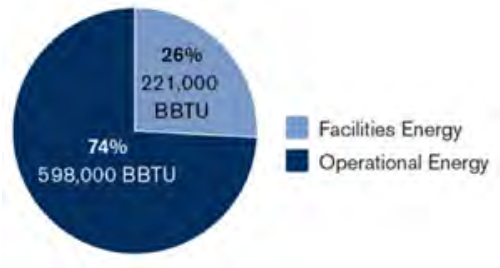
This research is funded by the California Energy Commission's Public Interest Energy Research (PIER) program.

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Berkeley Lab Continues to Support the U.S. Department of Defense in Promoting Energy Efficiency and National Security



U.S. Department of Defense energy consumption.

The U.S. Department of Defense (DoD) is the single largest consumer of energy in the nation. It accounted for approximately 1 percent of the national energy demand in fiscal year 2011, which added up to a $20 billion energy bill. Beyond the large expenditure, this level of energy consumption makes DoD vulnerable to energy supply disruptions, both from imported petroleum and the power grid.

To improve its energy security, DoD has expanded its funding for and focus on energy efficiency and distributed energy over the last decade. This emphasis has spurred a strong working relationship between Lawrence Berkeley National Laboratory (Berkeley Lab), other research laboratories, industry leaders, and military agencies.

During that decade, Berkeley Lab's particular focus with DoD has been on providing military agencies with technical support, research, computer modeling, energy analysis, and technology demonstrations at domestic facilities. These activities have saved money, increased energy security, and provided a proving ground for efficient technologies that can be used in many applications.

In the last few years, however, this focus has started to change, according to Rich Brown of Berkeley Lab's Building Technology and Urban Systems Department. The U.S. Department of Defense has begun to set its energy-saving sights beyond just its building stock.

"All those domestic, fixed facilities together only represent about a quarter of DoD's energy use," said Brown. "The majority of military energy savings potential these days is in what's called 'operational energy.'"

Operational energy is used for planes, ships, tactical vehicles, and expeditionary bases such as the current base camps in Afghanistan that serve as temporary outposts for the military staff deployed there.

"Heating and air conditioning tents in extreme climates with diesel generators uses a lot of energy," Brown said. "This is an example of where the focus is going now."

Exterior view of the military shelters used in the Crimson Viper demonstration.

However, operational energy savings is about more than just saving money, Berkeley Lab's Sustainable Federal Operations Director Charles Williams points out. "It is also about saving lives. Many lives have been lost, and many injuries sustained in delivering fuel to forward operating bases," he says. Having fuel and power on hand when needed is critical to completing a military mission successfully—and energy efficiency is one way to secure it. In that vein, DoD plans to spend more than $900 million on reducing DoD's demand for operational energy in fiscal year 2013 alone. Energy-efficiency plans are part of an overall operational energy plan that will reduce demand for energy, expand and secure the supply of energy, and build energy security into the future force. Energy efficiency has become part of a military tactical plan for energy security, and Berkeley Lab—along with other national laboratories—ultimately will play a role in developing the technologies on which they will rely.

"The wars in the Middle East have made the military aware that they are fighting because of oil and that energy is critically important to their ability to function in these countries," Williams said. There is also increased awareness that energy supplies in forward operating bases and fuel for mobile weapons platforms are critical to combat effectiveness.

Test of advanced lighting controls in a military shelter at Crimson Viper technology demonstration.

Just this summer, DoD moved into the first phase of one program aimed at reducing energy use at expeditionary outposts in tropical climates: the $3.85 million Transformative Reductions in Operational Energy Consumption (TROPEC) project. Through this project, DoD hopes to reduce energy use in these environments 50 percent by 2016.

Berkeley Lab is part of a team awarded TROPEC funding to test and demonstrate technologies for reducing energy use in DoD's forward operating bases, under the leadership of DoD's Pacific Command, which is responsible for security in the Asia/Pacific region. Berkeley Lab's role is to identify and test technologies for efficient lighting, electronics, and data processing operations.

The TROPEC program includes three phases: selecting applications from academia and industry for technologies to demonstrate; testing the technologies and products in the laboratory; and operational testing at military exercises throughout the Asia/Pacific region. At a technical demonstration, "Crimson Viper," held in Thailand in the summer of 2012, Berkeley Lab tested efficient lighting control technologies that are already in use for civilian applications but have never been demonstrated for military/portable facilities in tropical climates. The test showed that these lighting control technologies can reduce lighting energy use in military tents by 50 percent or more.

Efficiency on the Home Front

Despite this new focus on operational energy, there is still momentum and potential to continue energy efficiency work at DoD's facilities here in the United States. Berkeley Lab's current domestic work for DoD is part of a tapestry woven over the

last decade to increase energy efficiency at domestic military bases and shipyards. These projects fall into several categories: technology demonstrations, alternative financing support, high-tech facility energy assessments, training, and other DoD projects.

Technology Demonstrations and Validations

The U.S. Department of Defense's Environmental Security Technology Certification Program (ESTCP) was established in 1995 to fund demonstrations of energy efficiency and renewable energy technologies that have already been proven in the laboratory and limited commercial markets but have not been proven yet in DoD applications.

Under ESTCP, Berkeley Lab has participated in demonstrations at bases in Arizona, Illinois, California, Maryland, and Washington, D.C. The technologies tested (outlined below) include building-integrated photovoltaics, daylighting sensors and controls, a microgrid made from the batteries of an electric vehicle fleet, and computer modeling.

- **Integrating Energy Information Systems and Model-Based Diagnostics, Washington Navy Yard, Washington, D.C.** (2012–ongoing)

  Berkeley Lab is providing new diagnostic capabilities for the energy information systems at the Washington Navy Yard with a goal of reducing central plant energy use by 10 percent. Berkeley Lab is providing the existing on-site military and contract personnel with tools that reveal problems with site operations and ways of improving them. Unlike similar projects, the Washington Navy Yard provides a demonstration that integrates advanced diagnostics with commercial tools at an operating facility with numerous operators and user groups.

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- **Daylighting Control Technologies Demonstration at Fort Irwin, California** (2010–ongoing)

  Berkeley Lab has been tasked with retrofitting and testing lighting and control technologies in three buildings at Fort Irwin, including a combined wireless occupancy/daylight detector, a full-featured control system for building-wide lighting control, and a system that combines wireless lighting control with automated shading devices. Results of the demonstration showed energy savings from 20 to 60 percent, due in part to light level adjustments overall.

  Berkeley Lab Contact: Francis Rubinstein, FMRubinstein@lbl.gov

- **Building-Integrated Photovoltaics Demonstration at the Marine Corps Air Station in Yuma, Arizona** (2009–2011)

  Berkeley Lab provided technical assistance to install and monitor photovoltaic technology integrated into a solar-reflective "cool roof" on an office building at the Yuma, Arizona, air base. Berkeley Lab instrumented the roof, gathered data, and analyzed the building energy savings and PV energy generation attained from installing the building-integrated photovoltaic roof.

  Berkeley Lab Contact: Ronnen Levinson, RMLevinson@lbl.gov

Drill Hall at Naval Station Great Lakes.

- **Energy Efficiency Modeling Demonstration at Naval Station Great Lakes** (2009–2011)

  Partnering with United Technologies, Berkeley Lab used computer simulation to monitor building performance, flag the problems identified, and diagnose operational faults affecting energy performance. Corrections were made to the lighting schedule and the chiller controls; comparable corrections could be identified at other military sites and then implemented by military personnel at those sites to save energy and money.

  Berkeley Lab Contact: Philip Haves, PHaves@lbl.gov

- **Plug-in Vehicle Microgrid Demonstration at Los Angeles Air Force Base** (2012–2014)

  The military has about 300,000 non-technical vehicles in their fleet. Those vehicles represent a significant opportunity for both energy and emissions savings, as well as for providing a distributed energy resource. With both DoD and California Energy Commission support, Berkeley Lab is providing software and technical assistance at the Los Angeles Air Force Base, which is converting its fleet to electric vehicles. The project will demonstrate how the electric vehicles could function as an aggregated battery to provide a controllable generation resource directly to the California Independent System Operator. Providing the service could potentially raise enough revenue to offset the higher overall cost of an all-electric fleet. Electric vehicles could also be integrated with bases to provide emergency onsite power generation, load control, and energy storage. Berkeley Lab is developing software that monitors and optimizes the use of the vehicles to maximize revenue for this demonstration. The goal is to identify the extent of economic benefits from converting this fleet—and eventually the entire non-tactical military fleet—to electric vehicles.

  Berkeley Lab Contact: Chris Marnay, ChrisMarnay@lbl.gov

Energy Savings Performance Contract Financing Support

Energy savings performance contracts (ESPCs) allow federal agencies to accomplish energy-savings projects without up-front capital costs and without special congressional appropriations. Berkeley Lab has provided support to DoD from the administrative side of the ESPC program—helping the Navy streamline its ESPC procurement process; providing a report to Congress on the feasibility of using ESPCs in non-building applications; and assessing measurement and verification practices for the Army Corps of Engineers' ESPC program.

- **Site Data Package Template for Energy Conservation Measures** (2009–2010)

  Berkeley Lab provided technical assistance in developing a template for a site data package—a summary of information for prospective bidders to gain a clean picture of the facility to evaluate and propose energy projects the Navy is interested in developing. The Navy requested the development of the site data package as a key element to streamlining the selection of energy service companies and accelerating ESPCs.

  Berkeley Lab Contact: Charles Williams, CHWilliams@lbl.gov

- **Study for Congress on the Feasibility of Using ESPCs in Non-Building Applications** (2010)

  As part of a report to Congress on the potential energy and cost savings in non-building applications in DoD and civilian agencies, Berkeley Lab provided a feasibility study for using ESPCs. (The draft is currently in Office of Management and Budget concurrence review.) Non-building applications include military fleets and weapons platforms, other federal agency fleets, and non-building assets such as electric generation and water transport facilities. In non-civilian applications alone, potential ESPCs were estimated to amount to approximately $1 billion/year from a total project investment of $9.9 billion. In non-civilian applications alone, potential ESPCs were estimated to amount to approximately $1 billion/year from a total project investment of $9.9 billion.

  Berkeley Lab Contact: Charles Williams, CHWilliams@lbl.gov

- **Technical Assistance and Review of the Army Corps of Engineers' Energy Savings Performance Contracts Program** (2010)

  Berkeley Lab assessed the measurement and verification practices and supporting activities for the Army Corps of Engineers' ESPC contract and program. Activities included a site visit to the Army Corps' support staff office, the review of numerous project and policy documents, and recommendations for process improvement.

  Berkeley Lab Contact: Charles Williams, CHWilliams@lbl.gov

Other DoD Projects

Over the years, Berkeley Lab has helped military agencies reduce energy costs and energy use in military bases, data centers, and laboratories across the nation. In addition, it has provided special assistance to Congress regarding research on indoor environment threat assessment.

Hazard assessment modeling (from EETD researcher Michael Sohn in collaboration with colleagues at Lawrence Livermore National Laboratory.)

- **Indoor Hazard Assessment Using the Joint Effects Model** (2012–ongoing)

  Working for the Defense Threat Reduction Agency (the DoD's combat support agency for countering weapons of mass destruction), Berkeley Lab has been conducting indoor environment research on chemical or biological agent exposure using the Joint Effects Model. Berkeley Lab is improving the software, conducting research on how to predict the indoor effects from an outdoor plume, and developing new decision analysis approaches to study hazard assessment problems. The group also conducts research on algorithms for operating sensor networks in buildings to detect and locate hazards in real time, and on air filter requirements that are designed to keep hazards out of shelters and other facilities. Their research supports both permanent and temporary facilities.

  Berkeley Lab Contact: Michael D. Sohn, MDSohn@lbl.gov

- **Energy Assessments of Data Centers and Laboratories** (2009–ongoing)

  Berkeley Lab provided energy assessments, training, and technical assistance to increase the energy efficiency and operations in data centers and laboratories as part of 15 projects. These projects include the Maui High Performance Computing Center, the Defense Enterprise Computing Center, and military bases in Hawaii, Maryland, Virginia, Ohio, and Mississippi. All 15 projects resulted in recommendations that, if implemented, could save more than 14,000 megawatt-hours annually, reduce annual carbon emission by 13,300 metric tons annually, and result in simple paybacks of less than three years on each project.

  Berkeley Lab Contact: Dale Sartor, DASartor@lbl.gov

- **Energy Audits at 10 Navy Bases on the West Coast** (2004)

  Berkeley Lab provided engineering services during energy audits in 49 buildings on 10 Navy installations in the Western Power Grid Region. The Lab identified measures to reduce energy and demand and conducted scoping and in-depth assessments of the chosen facilities in each installation. The result was a rigorous analysis of project cost, estimated savings, payback, and savings-to-investment ratio that was detailed in assessment reports for each of the installations. These reports identified measures that could be implemented to achieve an estimated demand reduction of more than 3,000 kilowatts and energy savings of $4 million/year, with an average payback of 4.5 years.

  Berkeley Lab Contact: Charles Williams, CHWilliams@lbl.gov

—Kyra Epstein

Berkeley Lab Project History with DoD

DOD Agency	Project	Date	LBNL Contact
All	Indoor hazard assessment using the Joint Effects Model	2012–ongoing	Michael D. Sohn MDSohn@lbl.gov
All	TROPEC program: lighting, electronics, and data center research	2012–ongoing	Rich Brown REBrown@lbl.gov
Navy	Integrating energy information systems and model-based diagnostics, at Washington Navy Yard, Washington, D.C.	2012–ongoing	Jessica Granderson JGranderson@lbl.gov
Air Force	Optimal scheduling of Air Force demonstration plug-in electric vehicles	2012–2014	Chris Marnay ChrisMarnay@lbl.gov
Army	Daylighting control technologies demonstration at Fort Irwin near Barstow Army Base, California	2010–ongoing	Francis Rubinstein FMRubinstein@lbl.gov
Army	Technical assistance and review of the Army Corps of Engineers' Energy Savings Performance Contracts program	2010	Charles Williams Sustainable Federal Operations, FEMP
Various branches	Study for Congress on the feasibility of using Energy Savings Performance Contracts in non-building applications	2010	Charles Williams Sustainable Federal Operations, FEMP
Army, Navy, Air Force	Energy assessments of data centers and laboratories	2009–ongoing	Dale Sartor DASartor@lbl.gov
Navy	Building-integrated photovoltaics demonstration at Yuma, Arizona, Marine Corps Air Station	2009–2011	Ronnen Levinson RMLevinson@lbl.gov
Navy	Energy efficiency modeling demonstration at Chicago Naval Station	2009–2011	Phil Haves PHaves@lbl.gov
Navy	Site Data Package Template for Energy Conservation Measures	2009–2010	Charles Williams CHWilliams@lbl.gov
Navy	Energy audits at 10 Navy bases on the West Coast	2004	Charles Williams CHWilliams@lbl.gov

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

The Installed Price of Solar PV in the U.S. Continues Its Rapid Decline

The installed price of solar photovoltaic (PV) power systems in the United States fell substantially in 2011 and through the first half of 2012, according to the latest edition of *Tracking the Sun*, an annual PV cost-tracking report produced by Lawrence Berkeley National Laboratory (Berkeley Lab).

The U.S. median installed price of residential and commercial PV systems completed in 2011 fell by roughly 11 to 14 percent from the year before, depending on system size, and in California prices fell by an additional 3 to 7 percent within the first six months of 2012. These recent installed price reductions are attributable, in large part, to dramatic reductions in PV module prices, which have been falling precipitously since 2008.

The report indicates that non-module costs—such as installation labor, marketing, overhead, inverters, and balance of system—have also fallen significantly over time. "The drop in non-module costs is especially important," notes report co-author Ryan Wiser of Berkeley Lab's Environmental Energy Technologies Division, "as these costs can be most readily influenced by local, state, and national policies aimed at accelerating deployment and removing market barriers." According to the report, average non-module costs for residential and commercial systems declined by roughly 30 percent from 1998 to 2011, but have not declined as rapidly as module prices in recent years. As a result, non-module costs now represent a sizable fraction of the installed price of PV systems, and continued deep reduction in the price of PV will require concerted emphasis on lowering the portion of non-module costs associated with so-called "business process" or "soft" costs.

The report indicates that the median installed price of PV systems installed in 2011 was $6.10 per watt (W) for residential and small commercial systems smaller than 10 kilowatts (kW) in size and was $4.90/W for larger commercial systems of 100 kW or more in size. Utility-sector PV systems larger than 2,000 kW in size averaged $3.40/W in 2011. Report co-author Galen Barbose, also of Berkeley Lab, stresses the importance of keeping these numbers in context, noting that "these data provide a reliable benchmark for systems installed in the recent past, but prices have continued to decline over time, and PV systems being sold today are being offered at lower prices."

Based on these data and on installed price data from other major international PV markets, the authors suggest that PV prices in the United States may be driven lower through large-scale deployment programs, but that other factors are also important in achieving installed price reductions.

The U.S. solar PV market has grown rapidly over the past decade, as national, state, and local governments offered various incentives to expand the solar market and accelerate cost reductions. This fifth edition in Berkeley Lab's *Tracking the Sun* report series describes historical trends in the installed price of PV in the United States, and examines more than 150,000 residential, commercial, and utility-sector PV systems installed between 1998 and 2011 across 27 states, representing roughly 76 percent of all U.S. grid-connected PV capacity. Naïm Darghouth, also with Berkeley Lab, explains that "the study is intended to provide policy makers and industry observers with a reliable and detailed set of historical benchmarks for tracking and understanding past trends in the installed price of PV."

Prices Differ by Region and by Size and Type of System

The study also highlights the significant variability in PV system pricing, some of which is associated with differences in installed prices by region and by system size and installation type. Comparing across U.S. states, for example, the median

installed price of PV systems less than 10 kW in size that were completed in 2011 ranged from $4.90/W to $7.60/W, depending on the state.

It also shows that installed PV prices exhibit significant economies of scale. Among systems installed in 2011, the median price for systems smaller than 2 kW was $7.70/W, while the median price for large commercial systems greater than 1,000 kW in size was $4.50/W. Utility-scale systems installed in 2011 registered even lower prices, with most systems larger than 10,000 kW ranging from $2.80/W to $3.50/W.

In addition the study found that:

- the installed price of residential PV systems on new homes has generally been significantly lower than the price of similarly sized systems installed as retrofits to existing homes,
- building-integrated PV systems have generally been higher priced than rack-mounted systems, and
- systems installed on tax-exempt customer sites have generally been priced higher than those installed at residential and for-profit commercial customer sites.

Price Declines for PV System Owners in 2011 Were Offset by Falling Incentives

State agencies and utilities in many regions offer rebates or other forms of cash incentives for residential and commercial PV systems. According to the report, the median pre-tax value of such cash incentives ranged from $0.90/W to $1.20/W for systems installed in 2011, depending on system size. These incentives have declined significantly over time, falling by roughly 80 percent over the past decade, and by 21 to 43 percent from just 2010 to 2011. Rather than a direct cash incentive, some states with renewables portfolio standards provide financial incentives for solar PV by creating a market for solar renewable energy certificates (SRECs), and SREC prices have also fallen dramatically in recent years. These declines in cash incentives and SREC prices have, to a significant degree, offset recent installed price reductions, dampening any overall improvement in the customer economics of solar PV.

—Allan Chen

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Tracking the Sun V: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2011, by Galen Barbose, Naïm Darghouth, and Ryan Wiser [PDF [http://emp.lbl.gov/sites/all/files/LBNL-5919e-REPORT.pdf]].

In conjunction with this report, LBNL and the National Renewable Energy Laboratory (NREL) have also issued a jointly authored summary report that provides a high-level overview of historical, recent, and projected near-term PV pricing trends in the United States. That report summarizes findings on historical price trends from LBNL's *Tracking the Sun V*, along with several ongoing NREL research activities to benchmark recent and current PV prices and to track industry projections for near-term PV pricing trends. The summary report documents further installed price reductions for systems installed and quoted in 2012.

The joint NREL/LBNL report, *Photovoltaic (PV) Pricing Trends: Historical, Recent, and Near-Term Projections* [PDF [http://www.nrel.gov/docs/fy13osti/56776.pdf]].

The research was supported by funding from the U.S. Department of Energy's Solar Energy Technologies Program of the Office of Energy Efficiency and Renewable Energy.

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

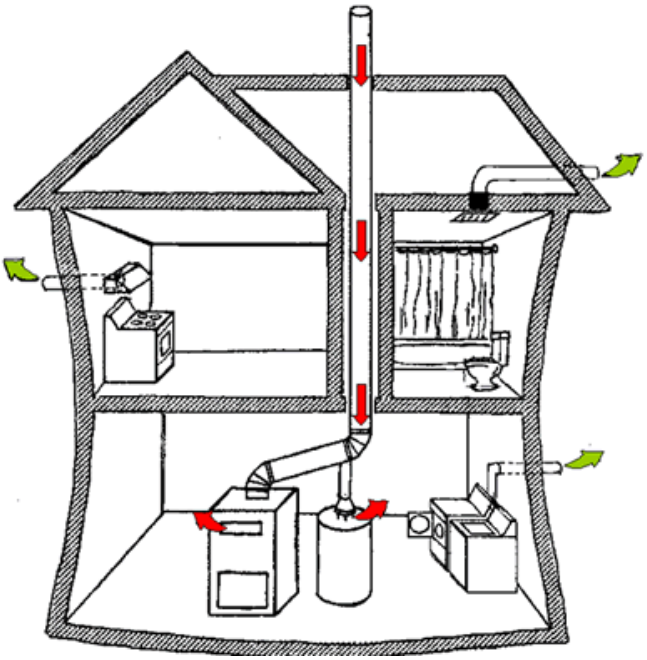
Reducing Barriers to Residential Building Air Tightness: Assessing Safety Diagnostics for Atmospherically Vented Combustion Appliances

Air sealing of homes to reduce the uncontrolled entry of outdoor air is typically among the most cost-effective retrofit measures to reduce energy consumption and associated greenhouse gas emissions. Airtight envelopes are at the center of energy efficient upgrade practices promoted by the California Energy Commission and the U.S. Department of Energy's (DOE's) Building America and Low-Income Weatherization programs.

However, tighter houses present potential health hazards to occupants because they depressurize more readily when using exhaust fans, including bathroom fans and those in range hoods and dryers. Depressurization increases the likelihood that the ordinary, upward exhaust flow of a vented combustion appliance—such as a water heater or furnace—will be reversed in a process called "backdrafting." Backdrafting can cause combustion exhaust products to spill into the home rather than being vented upward and out through the vent. This spillage can expose residents to hazardous air pollutants that are produced by the combustion appliance burners.

Concerns about increasing backdrafts and spillage are limiting air sealing in many homes, driving costly fixes in other homes, and requiring expensive testing in homes that are being considered for air sealing but also contain vented combustion appliances within the living space.

For five months, we have been compiling 25 years worth of information regarding combustion appliance venting and safety diagnostics into a new report. The report shines light on research needs and opportunities to improve residential energy efficiency and indoor air quality. With funding from the California Energy Commission and DOE, the Residential Building Systems group of the Environmental Energy Technologies Division is working to reduce barriers to air tightening and combustion appliance venting.



Depressurization in the home can suck air and combustion products back down the chimney or flue and into the house, as shown by the red arrows in the diagram. U.S. EPA.

The report is the first known document to compile and critically review literature related to combustion appliance venting. It is expected to steer efforts to improve safety inspections for gas appliances in homes that are air tightened for energy efficiency.

A number of studies have attempted to assess the performance of current combustion safety diagnostics in identifying appliances and homes that will encounter backdrafting and spillage events. Much of this research focuses on comparing results of short-term "stress" tests with results from in-home monitoring over periods of a week or more. Results from stress tests typically identified problematic appliances and homes for which there was no sustained spillage over the monitoring period. Available monitoring data support, but are not adequate to prove, the team's hypothesis that spillage is uncommon, since it requires the coincidence of environmental conditions, building characteristics, and exhaust fan usage.

Although the body of existing research provides some assessment of existing combustion safety diagnostics, the objectives of the diagnostics are not clearly defined and do not provide a clear indication of the risk of spillage during normal operation. Research also suggests that existing diagnostics are not reliable and repeatable predictors of venting performance.

A key deficiency of the research is that the test methods do not explicitly treat backdrafting and spillage as both physical and statistical phenomena. The statistical phenomenon associated with spillage is especially important because health risk depends on how frequently spillage occurs when an appliance emits a large amount of pollutants. Therefore, more research is required to quantify the frequency of test "failure" occurrence throughout the building stock, as well as to assess the statistical effects of weather (especially wind) on house depressurization, and in turn on combustion appliance venting.

In June 2012, DOE's Building America Program and the Partnership for Advanced Residential Retrofit (PARR) hosted an expert meeting on combustion safety, to identify gaps and barriers in the research and progress toward harmonization of existing combustion safety protocols. We presented the results of the team's research, and we believe them to be a valuable asset for advancing harmonization of those protocols. A number of meeting participants agreed that incorporating physical and statistical phenomena into existing combustion safety diagnostics is a valid approach to mitigating risk.

The next step in this project will be to use simulation software to identify health risks associated with combustion spillage. The goal of the project is to develop, by the summer of 2013, a more reliable diagnostic method that incorporates the physical and statistical phenomena associated with backdrafting and spillage to mitigate risk.

—Vi Rapp

For more information, contact

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Vi Rapp is a postdoctoral fellow in the Residential Buildings Group of the Environmental Energy Technologies Division.

Rapp, V.H., B.C. Singer, J.C. Stratton, and C.P. Wray. 2012. *Assessment of Literature Related to Combustion Appliance Venting Systems*. LBNL Report 82163 [PDF [http://buildings.lbl.gov/sites/all/files/Rapp%20LBNL%205798E.pdf]].

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

How to Unplug and Save Money

Would you be satisfied with your home if its energy use fell only a third when you were away? Probably not, but that's how most office buildings behave. That's because employees often leave computers, printers, desk lamps, break-room appliances, and other so-called "plug loads" running around the clock.

Steven Lanzisera

As companies upgrade to energy-efficient lighting and temperature control systems, the residual energy-saving opportunities from plug loads will loom ever larger, notes Steven Lanzisera [http://eetd.lbl.gov/staff/steven-lanzisera], an energy analyst at Lawrence Berkeley National Laboratory (Berkeley Lab). In fact, such loads will likely represent close to 30 percent of U.S. building site energy use by 2030, according to Berkeley Lab estimates.

Lanzisera spoke recently to medium- and large-commercial customers at a Pacific Gas and Electric (PG&E)-sponsored seminar on energy solutions in Oakland. He has unique insights based on a long-term study of plug loads at a 90,000-square-foot building on Berkeley Lab's campus, which houses about 450 regular occupants. In temperate spring months, when air conditioning is turned off, plug loads account for 40 percent of the building's entire electricity consumption.

At first glance, the number of different plug loads in such a building "makes your head spin," Lanzisera says. They include portable fans, paper shredders, coffee makers, electric staplers, and wireless headsets. "There are so many kinds, people don't know where to get started," he observes. "That's one of major reasons people don't address plug loads."

But close inspection showed that more than three-quarters of energy use by plug loads at Berkeley Lab's building was accounted for by IT equipment: computers (50 percent), computer displays and TVs (12 percent), printers and copiers (11 percent), and networking equipment (6 percent). And most of this energy was consumed during nights and weekends when employees were not using the equipment. That means the IT department is in a great position to implement office-wide energy solutions.

The first and simplest energy-saving remedy, Lanzisera says, is to make sure people buy only efficient products. Replacing an older 20-inch LCD monitor with a new ENERGY STAR-rated 24-inch monitor will increase usable screen area 44 percent while reducing energy use by a third. That's practically a free lunch.

The second remedy is to tackle unnecessary nighttime loads with power management solutions. It turns out that the Berkeley Lab building's computers draw substantial power—25 kilowatts—even late at night and early morning when almost no one is around. That's almost 60 percent as much as they draw during normal business hours. Apparently many users don't take advantage of their computers' existing power management functions.

More than half of that off-peak energy use could be slashed by installing remote power management software that lets the IT department shut down or wake up computers by centralized commands. (That capability also gives the IT folks the capability to install remote backups and upgrades at night, when they don't disrupt normal work.)

Lanzisera figures that such a solution would save about 150,000 kilowatt-hours per year, or 12 percent of the building's entire annual electricity consumption. "Similar savings are probably realistic across many enterprises," he says.

For many other plug loads, the simplest solution is to install smart plug strips, which use occupancy sensors, timers, or other mechanisms to turn devices on or off as needed. Such strips might save Berkeley Lab's building a hefty 75,000 kilowatt-hours per year.

If Ben Franklin were alive today, he'd probably title Lanzisera's presentation, "A kilowatt-hour saved is a kilowatt-hour earned." Taken individually, each plug load "just isn't that much," Lanzisera says. "In aggregate, however, across an organization, they can be quite significant, and you can save a substantial amount of energy."

Researchers like Lanzisera, and PG&E's energy efficiency experts, are helping make such savings opportunities as easy and profitable as possible.

—Jonathan Marshall

Additional information:

Contact Jonathan Marshall at Jonathan.Marshall@pge.com.

This article was originally published in PG&E Currents [http://www.pgecurrents.com/2012/08/30/how-to-unplug%E2%80%94and-save-money/]. Reprinted with permission.

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Study Finds Reasons to Improve Indoor Air Quality in Childcare Facilities

A first-of-its-kind study of the indoor air quality of 40 childcare centers in California finds that most concentrations of contaminants in the air are well within state and federal guidelines, although a few chemicals such as formaldehyde substantially exceeded guidelines.

Thomas McKone

Randy Maddalena

Thomas McKone and Randy Maddalena of Lawrence Berkeley National Laboratory (Berkeley Lab) participated in the study, which was led by Asa Bradman and researchers in the University of California, Berkeley's Center for Environmental Research and Children's Health. McKone has a joint appointment at the School of Public Health and in Berkeley Lab's Environmental Energy Technologies Division (EETD). Maddalena is a scientist in EETD.

"Although most of the volatile organic compounds that we commonly measure indoors are similar in childcare facilities and other indoor environments like homes and schools, our findings suggest that there are a lot more chemicals in the air than what we commonly measure. In addition to the target VOCs in our study, we identified over a hundred other VOCs in the air, many of which do not have reference exposure levels." says Maddalena.

The study is the first to provide a detailed analysis of environmental contaminants and exposures for children in early childhood education facilities (ECE). These facilities include home-based childcare providers, private for-profit or non-profit preschools, and programs run by government agencies and religious institutions.

The study was funded by the California Air Resources Board (CARB), which provides guidance on its website about how childcare centers can reduce the concentration of these chemicals in the air. One of CARB's responsibilities is to regulate the emissions of indoor air pollutants in California.

Volatile Organic Compounds in the Air

The researchers measured more than 40 volatile organic compounds (VOCs) in the air of these facilities, although, they say, "most concentrations were usually below levels of concern." Common sources of VOCs are cleaners and personal care products.

However, formaldehyde, acetaldehyde, chloroform, and benzene or ethylbenzene exceeded the child-specific Safe Harbor Levels established by California's Office of Environmental Health Hazard Assessment (OEHHA). Formaldehyde and acetaldehyde are known respiratory irritants and carcinogens.

It is important to better understand the impact of these concentrations. According to the report, "because children exhibit exploratory behaviors that place them in direct contact with contaminated surfaces, they are likely to be exposed to any contaminants present. Children have higher exposures because they breathe more air, eat more food, and drink more water per unit of body weight compared to adults. They are also less developed immunologically, physiologically, and neurologically, and therefore may be more susceptible to the adverse effects of chemicals and toxins."

Formaldehyde concentrations in the air exceeded reference exposure levels in 35 of the facilities. It is typically emitted from furniture containing composite wood products like plywood, fiberboard, or particle board, but it can be emitted from other indoor sources including carpets and carpet pads; paints and coatings; permanent press clothing, furniture fabrics, and draperies; personal care products; and indoor combustion sources such as gas ranges and fireplaces.

"More research needs to be conducted on the understanding the health risks posed by indoor environmental contaminants in these facilities," says Maddalena. "We also need to identify better strategies to reduce indoor sources of these chemicals."

Some of CARB's recommended strategies for reducing formaldehyde in the air include:

- Purchase products containing little or no formaldehyde.
- Use ventilation systems and open windows.
- Clean frequently to minimize dust, using a vacuum cleaner with a HEPA filter or a wet mop for hard surface floors.
- Clean out cabinets and garages to eliminate older pesticides, solvents, and cleaning products that may leak, in order to help reduce indoor levels of pesticides and harmful chemicals.
- Assure adequate ventilation to bring in outdoor air.

The study's authors are Asa Bradman, Fraser Gaspar, Rosemary Castorina, and Elodie Tong-Lin (Center for Environmental Research and Children's Health, University of California, Berkeley); Thomas McKone (University of California, Berkeley, School of Public Health and Lawrence Berkeley National Laboratory), and Randy Maddalena (Lawrence Berkeley National Laboratory).

—Allan Chen

Additional information:

California Air Resources Board press release [http://www.arb.ca.gov/newsrel/newsrelease.php?id=357].

A detailed fact sheet on this study and additional steps child-care centers can take [PDF [http://www.arb.ca.gov/html/fact_sheets/preschool_exposure.pdf]].

Information on ARB's regulation on composite wood and formaldehyde [PDF [http://www.arb.ca.gov/toxics/compwood/factsheet.pdf]].

Environmental Exposures in Early Childhood Education Environments report [PDF [http://www.arb.ca.gov/research/apr/past/08-305.pdf]].

LAWRENCE BERKELEY NATIONAL LABORATORY

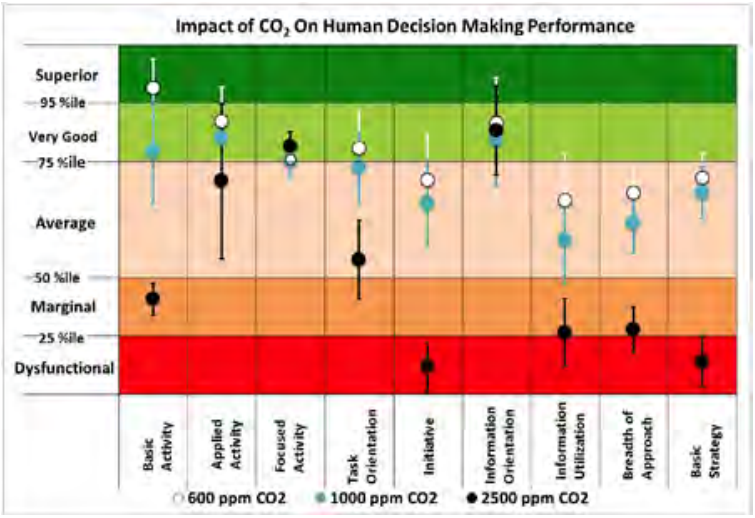
Environmental Energy Technologies Division

NEWS

Research Highlights

Increased Carbon Dioxide Concentration Impacts Human Performance

A research team from Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division and the State University of New York Upstate Medical University has found that increasing indoor carbon dioxide (CO_2) concentrations at the higher end of the range typically measured in buildings (1,000 parts per million [ppm] and 2,500 ppm) can reduce human decision-making performance.



Moderate and statistically significant decrements occurred in six of nine scales of decision-making performance when subjects were exposed to 1,000 ppm CO_2, relative to a concentration of 600 ppm, which is the concentration in a well-ventilated building. At 2,500 ppm, large and statistically significant reductions occurred in seven scales of decision-making performance.

Previous research has attributed associations of higher indoor carbon dioxide concentrations with impaired work performance, increased health symptoms, and poorer perceived air quality to other indoor air pollutants whose concentrations closely correlate with indoor CO_2 concentrations. Consequently many studies of indoor air quality use carbon dioxide concentration as a proxy for the concentrations of an array of other indoor air pollutants.

This study assessed the direct effects of CO_2 (within the range of indoor concentrations) on decision-making. Results suggest that carbon dioxide itself can have impacts on human performance.

The authors write: "The findings of this study, if replicated, would have implications for the standards that specify minimum ventilation rates in buildings, and would also indicate the need to adhere more consistently to the existing standards."

For more information, contact Mark Mendell, MJMendell@lbl.gov.

Satish U., M.J. Mendell, K. Shekhar, T. Hotchi, D. Sullivan, S. Streufert, W.J. Fisk, et al. "Is CO_2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO_2 Concentrations on Human Decision-Making Performance." *Environ Health Perspect*. doi:10.1289/ehp.1104789.

Funding for this work was provided by the Collaborative Activities for Research and Technology Innovation (CARTI), which is supported by the U.S. Environmental Protection Agency.

International Prize for Water Awarded to Team Led by Berkeley Lab's Ashok Gadgil

Ashok Gadgil

A team led by Lawrence Berkeley National Laboratory's (Berkeley Lab) Ashok Gadgil is the recipient of the 5th Prince Sultan Bin Abdulaziz International Prize for Water. Gadgil, head of the Lab's Environmental Energy Technologies Division and a professor of civil and environmental engineering at the University of California, Berkeley, will receive the Creativity Prize on behalf of the team. The prize recognizes his team for developing an innovative technology for affordable arsenic-safe drinking water in Bangladesh and nearby regions.

The biannual prize is named after HRH Prince Khaled Bin Sultan Bin Abdulaziz, Saudi Arabia's Assistant Minister of Defense and Aviation and Inspector General for Military Affairs. The prize comes with 1 million Saudi riyals (about $266,000) and a distinctive trophy.

The award citation noted that Gadgil received his recognition for "research [relating to] one of the greatest problems currently facing the water supply: the arsenic contamination of groundwater." The citation continues: "The Creativity Prize is being awarded to Dr. Ashok Gadgil's team at UC Berkley for developing an economical and effective way to treat arsenic contamination and restore the groundwater supply to potability for millions of poor people around the globe. Together, these achievements promise to save countless lives."

Says Gadgil, "We are pleased that this prize recognizes the depth of our scientific research. This ranges from analysis of materials using synchrotron-generated x-rays, to engineering design, and also the breadth of our work that spans social sciences, economics, consumer and organizational behavior, and financially viable business models."

Arsenic in drinking water occurs naturally in high concentrations in certain areas of the world, including Bangladesh, and is believed to be poisoning as much as 50 percent of that nation's population.

"My team members and I are thrilled that the international committee of distinguished water experts for this prize selected our work," says Gadgil, "which truly represents a team effort." Gadgil's team members for this award are: Susan Addy and Case van Genuchten from the University of California, Berkeley; Professor Joyashree Roy from Jadavpur University in Kolkata, India; and Robert Kostecki from Berkeley Lab.

The awards ceremony will be held in Riyadh, Saudi Arabia, in January 2013.

The Prince Sultan prize announcement [http://www.psipw.org/index.php?option=com_content&view=article&id=98&Itemid=284].

More on Gadgil's work at the Gadgil Lab website [http://GadgilLab.berkeley.edu].

Nanogrids Can Support Smart Grid Success

The Smart Grid promises to deliver the right amount of power to the right equipment at the right time and at the right price. However, fulfillment of this promise is dependent on precise control of electricity, and is being offered just as renewable generation and variable pricing structures introduce more challenges to grid operations.

Berkeley Lab's Bruce Nordman and Alan Meier, and Ken Christensen of the University of South Florida, offer a way to overcome those challenges in their article, "Think Globally, Distribute Power Locally: The Promise of Nanogrids." The authors outline how nanogrids—relatively small, locally operated grids—can manage local power supplies at a lower cost and reduced energy use. A nanogrid has at least one load or sink of power, a gateway to the outside, and a controller to distribute power, using price signals to mediate supply and demand. It is the most effective way to integrate local renewable generation and storage, and it incorporates features such as peer-to-peer power exchange, bidirectional power flow, and managed distribution to loads. By separating power distribution from functional control, nanogrids allow different devices to be powered differently; some with AC and some with DC. In areas where buildings produce power, as well as use it, nanogrids can be structured so that a building using less energy can share its electricity with another building with a higher need.

For developing countries, nanogrids offer a hedge against cost-intensive central station facilities and their transmission and distribution networks by allowing distributed generation to provide more of the electricity and smaller central facilities to be

built. Other benefits include secure communications, privacy, and local storage.

For more information on nanogrids, see Bruce Nordman's webpage [http://nordman.lbl.gov].

Bruce Nordman, Alan Meier, and Ken Christensen, "Think Globally, Distribute Power Locally: The Promise of Nanogrids," *Computer* September 2012, 45:9 pp 89–91.

Berkeley Lab Connecting BEST Center Students with Latest Research


Kristen Parrish


Mary Ann Piette

The National Science Foundation (NSF) awarded the Building Efficiency for a Sustainable Tomorrow (BEST) Center at Laney College in Oakland, California, with a four-year, $4 million grant. The BEST Center will develop curricula for two-year U.S. colleges to educate building control technicians and incorporate energy-efficient technologies and practices into their programs.

Scientists at Lawrence Berkeley National Laboratory (Berkeley Lab) will contribute to the BEST Center by providing the latest research in energy-efficient building technologies. Berkeley Lab's Environmental Energy Technologies Division (EETD) will provide technical information, webinars, and guest lectures to Laney College students.

"The focus will be on infusing energy efficiency wherever possible into the curricula for building technicians in two-year community college programs," says Kristen Parrish, former Post-Doctoral scholar at Berkeley Lab, now an Assistant Professor at Arizona State University' School of Sustainable Engineering and the Built Environment. "Berkeley Lab's participation in the project will allow Laney College students to connect with Berkeley Lab's research community and learn about cutting-edge research," adds Parrish.

The Center will leverage Laney's NSF-sponsored work to create certificate and degree programs to prepare technicians to maintain and optimize the performance of commercial buildings. BEST will provide its curricula to community colleges across the United States.

Laney College has offered courses in building technician education for more than 40 years. With the support of the National Science Foundation, Laney has expanded its Environmental Controls Technology program to include building automation systems, energy efficiency, and commercial building technician education. A goal of Laney's ECT program is to prepare technicians to be "change agents" in implementing cost-effective energy-efficiency measures in commercial and residential buildings.

Mary Ann Piette, EETD's Head of the Building Technology and Urban Systems Department, and James O'Donnell, EETD Postdoctoral Fellow, will work with Laney College staff on the BEST Center.

For more information on the BEST Center, see the BEST Center website [http://www.bestcte.org/].

Berkeley Lab's Ashok Gadgil Will Lead UC Berkeley's New Development Impact Laboratory

The University of California (UC), Berkeley, announced today that Ashok Gadgil, leader of the Environmental Energy Technologies Division at Lawrence Berkeley National Laboratory (Berkeley Lab), will lead the university's new Development Impact Laboratory (DIL). Gadgil is a Professor of Civil and Environmental Engineering at UC Berkeley.

Low-carbon technologies for food preparation, water purification, shelter, and public health are among those to be addressed by the new Development Impact Laboratory.

The United States Agency for International Development is funding DIL with up to $20 million under its new Higher Education Solutions Network (HESN). The network's purpose is to apply science and technology to solve key problems in health, food security, chronic conflict, and other global needs. UC Berkeley's DIL will be one of a network of USAID-funded labs at seven universities to conduct this research. In total, the universities participating in HESN will receive up to $130 million over five years to fund the research.

"DIL is a truly exciting opportunity to bring world-class science and technology innovation to bear on some of the most difficult problems of international development in poor societies," says Gadgil. "We are thrilled to be selected by USAID to be part of this exclusive group, from close to 500 applicant teams. Our selection also indicates how well our proposal aligns with the vision of the Science and Technology team at USAID seeking to undertake development work in new ways."

Ashok Gadgil at work on water purification technology.

Berkeley Lab's LBNL Institute for Globally Transformative Technologies (LIGTT) will participate in the work of DIL, partnering with them in areas where LIGTT is performing research, including health, water and sanitation, and urban poverty.

Institutional members of the DIL include UC San Diego, Lawrence Berkeley National Laboratory, Makerere University in Uganda, Indian Institute of Technology Bombay (India), University of Washington, University of Michigan, and Portland State University.

Several Berkeley faculty members will play key roles in the DIL project. Professor Shankar Sastry, dean of the college of engineering, will serve as its chief scientist. Professors Eric Brewer (Electrical Engineering and Computer Sciences), Daniel Fletcher (Bioengineering), Edward Miguel (Economics), and Ananya Roy (City and Regional Planning) also have significant major roles in the DIL project.

Read the UC Berkeley press release [http://newscenter.berkeley.edu/2012/11/08/usaid-gives-20m-for-global-development-initiatives-at-uc-berkeley/].

Read more about the Higher Education Solutions Network [http://www.usaid.gov/news-information/press-releases/usaid-launches-new-network-engage-students-and-universities].

Web Guide to Improving Existing Ventilation in California Homes and Apartments

RESAVE website.

The RESAVE website [http://resaveguide.lbl.gov/] is a guide that offers homebuilders and energy auditors working in California information on how to improve ventilation in existing residential buildings. The overall goal of this California Energy Commission Public Interest Energy Research (PIER) program is to help reduce the amount of energy and peak power used in homes to condition air that enters from outdoors.

Inadequate ventilation often leads to increased levels of moisture and pollutants in a home. A good mechanical ventilation system can not only save energy, but also help protect occupant health by reducing exposures to those pollutants.

Infiltration, the uncontrolled exchange of air through leaks and penetrations, typically accounts for over one-third of the total space conditioning energy. New homes typically spend the same fraction of energy on mechanical ventilation. The RESAVE program aims to reduce infiltration- and ventilation-related peak load and energy costs by 25 to 50 percent.

For more information on the RESAVE program, see the RESAVE website [http://resaveguide.lbl.gov/].

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division NEWS

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/]

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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.

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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.

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