LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

SUMMER 2012:
VOL. 11, NO. 1

In this issue of *EETD News*, you'll find reports of research ranging from the kitchen to the wind power industry and beyond. EETD scientists and engineers are developing technologies to use grid-connected buildings as a means of smoothing the intermittency of renewable power.

Others are studying emissions from cooking exhaust hoods—you're invited to take a survey to contribute to these studies. We also look at how researchers are increasingly predicting the properties of new materials from first-principle calculations to speed up the search for better batteries and other clean energy technologies.

A new program, B-PATH, is now available to help building designers calculate the life-cycle energy costs of structural building materials. You'll also find a report on the state of the U.S. wind power industry, and a report on how to estimate the savings from behavior-based energy efficiency programs.

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].

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

The Building as an Energy Storage Device: Fast Demand Response as a Solution to Intermittent Renewables

Sila Kiliccote

In 2020, if all goes according to plan, the state of California will get 33 percent of its electricity from renewable power, including solar and wind, as required by the state's Renewable Portfolio Standard. But wind doesn't blow all the time, and the sun doesn't provide as much power on cloudy days—renewable power is intermittent. This poses a problem for the electric grid's operators, who need to be able to exactly match the generation of electrical power with the demand for it at any given moment.

Because swings in the amount of available renewable power don't match the total demand for power from moment to moment, the balance has to come from somewhere, while the total power from clean energy sources must average out at 33 percent.

Another solution is to store renewably generated electricity in large, stationary grid-connected batteries, and supply power from them when renewable sources aren't providing enough in the moment. With current technology, this would be expensive, although research efforts are under way to develop less expensive energy storage technologies for the grid.

Scientists at the Environmental Energy Technologies Division (EETD) of Lawrence Berkeley National Laboratory (Berkeley Lab) have developed another solution that can help deal with intermittency: adjusting the power demand of large buildings automatically to more closely match the conditions on the electric grid. Their technological approach is called *automated demand response* (AutoDR), and their research was supported by the California Energy Commission's Public Interest Energy Research program, California utilities, the Bonneville Power Administration, and the New York State Energy Research and Development Authority.

Demand response is a set of activities usually carried out in commercial, industrial, and sometimes residential buildings that change, shed, or shift electricity use with the goal of improving electric grid reliability and managing costs. When demand for and the cost of electricity is high, building managers in large commercial and industrial facilities can, for example, dim lights or turn them off in unused areas, temporarily raise a building's temperature setpoint by a degree or two to reduce air conditioning use without impacting the building's occupants, or defer the use of certain industrial equipment until later, when power is cheaper. This reduces electric demand, or "load," and the possibility of grid failure.

"Our study suggests that fast-acting automated demand response in the commercial and industrial sectors is more cost-effective than grid-scale battery storage," says EETD scientist Sila Kiliccote, principal investigator of the research. "It offers grid operators a less expensive tool for managing the grid than battery storage. The infrastructure for demand response already exists and is growing in California and elsewhere."

Automated Demand Response Makes Inroads on a Grid Near You

Since the 1990s, EETD scientists have been working with California utilities, the state's Public Utilities Commission, commercial and industrial power consumers, and utilities around the world to test and deploy AutoDR technologies. AutoDR is a significant element of the "Smart Grid," an expression meaning that the operators, utilities, power generators, and customers on an electrical grid can respond in real-time to changes in the cost and availability of power with the help of software and hardware that monitors the state of the grid continuously.

The benefits of AutoDR and the Smart Grid include reduced chances of the grid failing during periods of high demand (a more reliable grid), lower power bills for customers who can reduce demand during these periods, and in the long run, greater energy efficiency and reduced greenhouse gas emissions.

Research by EETD scientists in cooperation with California electric utilities and large industrial and commercial customers has demonstrated that AutoDR reduces peak power use during periods of high demand. In response, the California Public Utilities Commission mandated the use of AutoDR by California's investor-owned electric utilities as a tool for managing the grid. Currently, there is more than 250 MW of AutoDR capacity in California. Electric power authorities globally are also beginning to add AutoDR to their grid management toolkits.

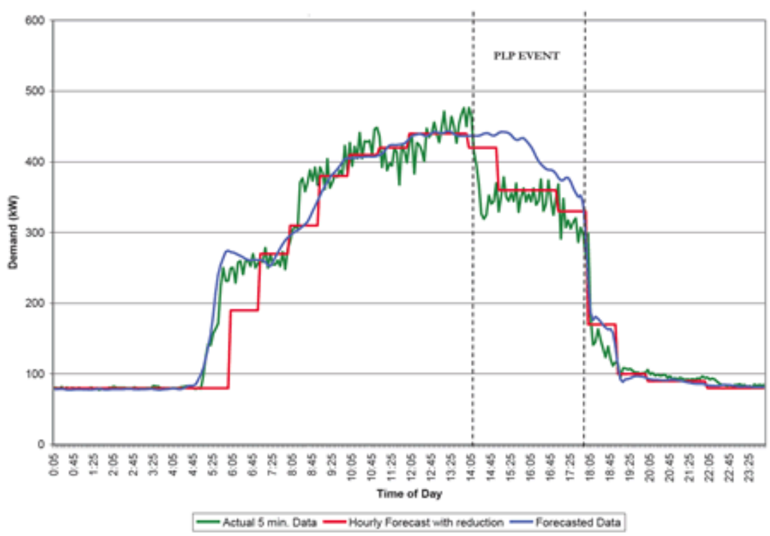
EETD scientists developed OpenADR, an Internet-based communications specification used by utilities, their customers, and electric grid authorities, to implement automated demand response in practice. It is one of the early Smart Grid standards. An organization of private sector companies, utilities, and research institutions called *OpenADR Alliance* is supporting OpenADR's adoption as a Smart Grid standard by providing certification for the devices that use the OpenADR standard.

Can Automated Demand Response Substitute for Batteries on the Grid?

To address the intermittency of renewable power, a group of EETD researchers set out to determine whether automated demand response could substitute for batteries or other forms of energy storage to balance the grid. Today, grid operators balance the demand for electricity exactly by purchasing power one day beforehand from sources such as hydroelectric plants and gas-powered combustion turbines.

These sources provide the peak load needed by the grid to meet the extra demand that shows up on hot summer afternoons (for air conditioning) or cold winter evenings (for heat). Grid operators make power purchases to meet peak load based on forecasts of how much demand is expected the following day.

Balancing the load on a grid supplied by a high percentage of intermittent renewables is a different problem from managing peak load, which can be estimated in advance. Power availability from renewable generation can ramp up or down rapidly, and requires grid operators to respond much faster than what the day-ahead market can provide—usually within minutes. Gas-fired power plants can provide fast response now, but because they emit air pollution, they do not meet the 33 percent renewable power requirement. Can demand response help?



Performance of Contra Costa County office building in non-spinning reserves tests led by Berkeley Lab researchers.

The answer is yes, according to a scoping study just published by EETD researchers David Watson, Nance Matson, Janie Page, Sila Kiliccote, and Mary Ann Piette, and colleagues at KEMA.

The research team looked at the hour-by-hour electric demand in California in the commercial and industrial sectors, estimating what percentage of their electric load could be shed through automatic demand response programs, and how long these loads could be shed. The study looked at loads that could be shed for two-hour durations and for twenty-minute durations. These intervals give grid operators a range of flexible resources to match fluctuations from renewable sources. They used data from the California End Use Survey 2004 to determine what commercial and industrial loads were suitable for demand response and currently or potentially controllable through energy management and control systems (EMCS) or system control and data acquisition systems (SCADA).

The study shows that these "fast AutoDR" sheds currently could provide between 0.18 and 0.90 gigawatts of load shedding.

"With modest investments to upgrade and expand use of automated control systems in commercial and industrial facilities," says Kiliccote, "the estimated shed potential could approximately double to between 0.42 and 1.8 gigawatts." One gigawatt is one billion watts of power.

The load shedding they identified is substantially less than what would be required to balance out the load fluctuations from intermittent renewable sources providing 33 percent of the state's power needs.

However, the study also found that the cost of using AutoDR to shed load is roughly one-half to one-quarter of the deployed cost of grid-scale battery storage using current battery technologies.

"Automated demand response has the potential to balance renewable intermittency in a cost-effective way," says Kiliccote. "Combined with grid-scale energy storage and other methods, it could be an important element of a suite of tools to help operators manage the grid."

Buildings as Energy Storage Devices

Thinking of buildings as energy storage devices is a key to understanding how demand response can be an active player in a Smart Grid system. Just as batteries store energy chemically, buildings (including refrigerated warehouses) store heat (or retain coolness) in their thermal mass.

The building operator can reduce a building's HVAC load—the energy required to heat, ventilate, or air-condition the building—temporarily, because a building will (within limits) retain its temperature for some period of time that depends on its mass, outside temperature, and other factors. The EETD researchers estimate that some buildings can shed 60 percent of HVAC-related electric demand for two-hour load shed events and 80 percent for 20-minute events for facilities with rooftop chiller units that can turn off compressors. These buildings usually include small offices, office areas within warehouse facilities, schools, lodging, and other facilities. Large office and college buildings that can make setpoint adjustments to reduce demand can shed 50 percent for both two-hour events and 20-minute events.

From previous studies, researchers know that buildings can dim or turn off lighting to reduce lighting electricity demand averaging 33 percent for a demand response event of up to four hours. Studies of retail facilities have shown a shed of 25 percent of their lighting electricity demand—display lighting requirements reduce their ability to shed load slightly compared to other commercial facilities.

Refrigerated warehouses are known from prior research to be able to reduce their loads by at least 25 percent or more for two hours without a serious change in temperature. Data centers can temporarily reduce their HVAC and lighting use as well, and water pumping for agriculture can be shifted to off-peak hours to respond to automated demand response events.

Together, these load sheds are a resource that can give grid operators one tool they need to manage an electric grid with intermittent supply resulting from a high percentage of renewable power. The grid will still need other tools for storing energy, such as grid-connected batteries and compressed air or pumped water storage. But the low cost of AutoDR makes it an attractive option for supplying some of the slack the grid will need as the state's and the world's renewable power generation capacity grows.

Follow-up research is planned. Says Kiliccote, "We need to better understand what percentage of each of these types of load sheds is available to address intermittency throughout the year. Also needed is a quantitative economic analysis of the scale up of AutoDR as a grid resource integrated with renewable and energy storage."

—Allan Chen

Additional information:

Sila Kiliccote
(510) 495-2615
SKiliccote@lbl.gov

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

Watson, D.S., N. Matson, J. Page, S. Kiliccote, and M.A. Piette (Lawrence Berkeley National Laboratory); K. Corfee, B. Seto, R. Masiello, J. Masiello, L. Molander, S. Golding, K. Sullivan, W. Johnson, and D. Hawkins (KEMA). *Fast Automated Demand Response to Enable the Integration of Renewable Resources* [http://eetd.lbl.gov/publications/15222/fast-automated-demand-response-to-enable-the-integration-of-renewable-resources]. California Energy Commission. LBNL-5555E.

Kiliccote, S., M.A. Piette, G. Ghatikar, E. Koch, D. Hennage J. Hernandez, A. Chiu, O. Sezgen, and J. Goodin. *Open Automated Demand Response Communications in Demand Response for Wholesale Ancillary Services* [http://drrc.lbl.gov/publications/open-automated-demand-response-communications-demand-response-wholesale-ancillary-servi]. November 2009. Presented at the *Grid-Interop Forum 2009*, Denver, CO, November 17-19, 2009. LBNL-2945E.

Kiliccote, S., P. Sporborg, I. Sheikh, E. Huffaker, and M.A. Piette. *Integrating Renewable Resources in California and the Role of Automated Demand Response*. November 2010. LBNL-4189E. [PDF [http://drrc.lbl.gov/sites/drrc.lbl.gov/files/lbnl-4189e.pdf]]

This research was supported by the California Energy Commission's Public Interest Energy Research program, California utilities, the Bonneville Power Administration, and the New York State Energy Research and Development Authority.

Lawrence Berkeley National Laboratory
Environmental Energy Technologies Division
NEWS

Calculating Properties of Materials from First Principles—A Tool for Faster Advanced Materials Development

Kristin Persson

Once the domain of guesswork and intuition, the field of developing new materials for advanced batteries and other applications is taking a turn towards a more systematic and predictive approach. Predicting the properties of new materials from "first principles" has become a scientific reality, thanks to the growth in computing power, a deeper understanding of how materials work, and databases of materials properties.

This will mean faster development of materials for high-energy batteries for electric vehicle applications, as well as better materials for many other applications, such as fuel cells and solar panels, high-strength materials, and catalysts.

Kristin Persson, a scientist in the Environmental Energy Technologies Division of Lawrence Berkeley National Laboratory, is moving forward on several fronts to predict the behavior of materials from first principles. In 2011, she and Gerbrand Ceder at the Massachusetts Institute of Technology (MIT) launched the Materials Project [https://www.materialsproject.org/]—a materials design gateway that allows users to browse existing materials (more than 20,000 currently) and their properties, modify them, and predict new materials using data-mining algorithms. [Read more about the project here [http://www.nersc.gov/news-publications/news/nersc-center-news/2011/materials-research-in-the-information-age/].]

The U.S. Department of Energy (DOE) is supporting the hunt for new materials through computation. Earlier this year, it announced that it would fund a new DOE Center for Functional Electronic Materials Design at $11 million over five years. Persson will be the Center's director, and Ceder, its associate director. The Center's purpose will be to conduct large-scale data generation, data-mining, and benchmarking for new materials. Scientists at Berkeley Lab; the National Energy Research Scientific Computing Center (NERSC); the University of California (UC), Berkeley; MIT; Duke; UC San Diego; and elsewhere will participate in the research.

Computation Can Accelerate Materials Innovation

Using the computational approach, researchers can apply first-principle calculations and great computing power to many materials at a time, to search out one whose properties may meet the needs of the application they are developing. "It takes 15 to 18 years to develop a material the traditional way, from the laboratory to commercial application," Persson says. "The lack of organized, comprehensive information about materials can cause delay during the scale-up to manufacturing."

As a result, materials innovation has been dependent on single investigators and intuition. Now, with high throughput first principles calculations on the properties of many materials, the Materials Project team has developed an organized, searchable database of materials properties. "This is assisting researchers in predicting the properties of new compounds, and it creates a new materials design environment," she adds.

Using the Materials Project database and tools, a researcher can ask a question such as, "are there any fluoride materials out there that would work as a cathode in a lithium ion battery?" The Materials Project database could screen "nature and beyond," as Persson puts it, for materials that have the desirable properties such as voltage, capacity, diffusivity, and stability, among other things.

As of July 2012, the Materials Project includes more than 20,000 compounds, as well as a materials explorer, a reaction calculator, a phase diagram application, a lithium battery explorer, a crystal toolkit, and a structure predictor. It has more than 2,500 registered users, has predicted more than 8,000 new structures using the structure predictor, and has generated more than 10,000 phase diagrams for its users.

Applying First Principle Calculations to Basic Research

Persson also uses these methods to solve basic scientific problems, focusing on one material at a time. The aim of the research is to develop better materials for higher-power or more-stable advanced batteries. For example, lithium-ion batteries, destined for such applications as plug-in hybrid and all-electric vehicles, need to have higher energy densities for greater range, lower cost, longer lifetimes, and a higher safety factor before they will be economical to use in vehicle applications.

"When I started, you couldn't do more than calculate very basic properties of materials," she says. "In the last 15 years, there has been an explosion of computing power, and advances in analytical methods. You can now submit a quantum mechanical calculation to a supercomputer with much less tuning and manual labor."

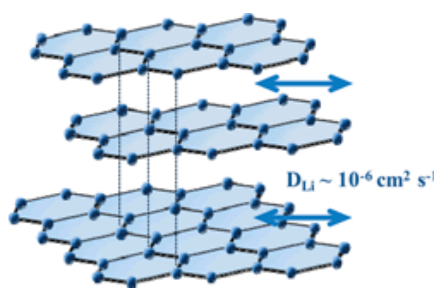
Persson has used first-principle calculations to answers questions about why certain experimental battery materials thought to have the ability to solve some of these problems have not yet lived up to their potential.

Graphitic carbons, for example, form a class of carbons that are most commonly found as the anode (the negative electrode) in a lithium-ion (Li-ion) battery. The material has been used since the commercialization of the first Li-ion battery by SONY, and its properties are thought to be relatively well understood. For example, it is well-known that the rate capability of graphitic carbons deteriorate significantly at lower temperatures, causing the battery to degrade and lose capacity to store energy. Loss of rate capability is usually tied to lowered lithium diffusivity (its ability to move through graphite), but measurements of lithium's diffusivity varies widely from one experiment to the next, making the root cause of the performance loss difficult to identify.

Calculating Graphite's Properties

In 2010, Persson and her colleagues Robert Kostecki at Berkeley Lab and Gerbrand Ceder of MIT teamed up to elucidate the problem. Persson and Ceder calculated the inherent diffusivity of lithium ions in carbon using first principles and found that the lithium's diffusivity was extremely high, suggesting that the diffusivity of the graphite was not the problem.

"We can take the pure graphite and calculate how fast the lithium moves around in there. This is inherent diffusivity. We were able to show that the graphite is really fast, she says. "This tells us that the graphite in itself is an extremely fast material." In fact, lithium ions could enter and leave a micron-sized graphite particle in less than 0.2 microseconds.



The molecular structure of graphite: carbon atoms in stacked sheets. In a battery, research results suggest that lithium ions could travel through graphite fastest when moving parallel to these sheets.

At a molecular level, graphite is made of carbon atoms in stacked sheets (see figure). The solution is to engineer the graphite material so that lithium ions can travel parallel to the sheets of graphite, instead of at grain boundaries.

With the proper materials engineering, it should be possible for the graphite to live up to its potential. "We would like to engineer the material so that the Li can travel along the fastest route," she says.

In parallel, a group led by Robert Kostecki at Berkeley Lab was able to measure the speed of lithium ions diffusing parallel to graphite's sheets of carbon, and perpendicular to it. The experimental results independently demonstrated that lithium ions diffuse rapidly through the graphite when traveling in between the graphene sheets, and slowly when traveling along the boundaries of graphite domains.

This concerted work pointed to a way of engineering a graphite anode to exploit the fastest pathway of diffusivity for lithium ions: creating graphite particles which are aligned radially, so that the planes of graphite's molecular structure are parallel to each other.

Other Research Directions

Persson has studied other battery materials as well, looking for such properties such as faster ionic diffusivity, and greater stability and energy storage capacity. For example, replacing five to ten percent of the cobalt (another candidate for cathodes in lithium batteries) in the layered materials with aluminum leads to a material with higher voltage, greater thermal stability, and lower electronic conductivity, yet it has a higher rate capability. Why? Persson and her colleagues found, using first principle calculations, that the aluminum lowers barriers to the migration of lithium ions when concentrations of lithium are low. Because cobalt is an expensive material, substituting cheaper aluminum would not only improve performance, but also lower material costs.

Persson's research continues to address materials for improved lithium ion batteries, even as she maps out other areas for future research. "We would love to look more at the surface properties of materials," she says. "First principle calculations can give you a very good handle on their bulk properties, which is the starting point. But surface properties are more difficult because they are more amorphous."

—Allan Chen

Additional information:

The Materials Project [https://www.materialsproject.org/]

Persson, Kristin et al. "Thermodynamic and kinetic properties of the Li-graphite system from first-principles calculations." *Physical Review B* 82.12 (2010): c2010 The American Physical Society.

Persson, Kristin et al. "Lithium Diffusion in Graphitic Carbon." *Journal of Physical Chemistry Letters*. 1 (8) 11767-1180 (2010).

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

Berkeley Lab Study Finds That Residential Cooking Exhaust Hood Performance Varies Widely

Cooking exhaust hoods designed for home kitchens vary widely in their ability to capture and vent away the air pollutants generated by the gas burners on cookstoves, according to a study by two Lawrence Berkeley National Laboratory (Berkeley Lab) scientists. Of seven representative devices they tested, the capture efficiency varied from less than 15 percent to more than 98 percent.


Brett Singer


Woody Delp

The research, by Woody Delp and Brett Singer of Berkeley Lab's Environmental Energy Technologies Division, measured cookstoves' pollutant capture efficiency, the sound level generated by their fans, and airflow. Cooking exhaust hoods vent such pollutants as carbon monoxide, nitrogen oxides, formaldehyde, and fine particulates such as soot that are generated during cooking.

While the exhaust hoods they tested varied widely in performance, they found that all exhaust hoods do a better job of capturing pollutants generated by the two back burners of a four-burner stove than those generated by its front burners.

"Even a moderately effective exhaust hood can reduce a stove user's exposure to pollutants," says Delp, "and using the back burners preferentially over the front burners helps reduce exposure even more." However, their research suggests that design improvements can increase the ability of hoods to capture pollutants and reduce their noisiness without increasing their energy use.

The study addresses the pollutants emitted by cookstove burners, but the process of cooking foods, for example by frying or stir frying, also generates pollutants. The research team has not confirmed that their results are applicable to cooking foods, but they believe that they are, and have funding for a follow-up study to confirm that the test method is applicable to assessing the capture of pollutants from the cooking process. They are also working on developing test standards that would allow for products to be rated for their performance in capturing pollutants.

Seven Representative Models Tested

Pollutant capture efficiency is expressed as the percentage of pollutants at the cooking surface captured by the exhaust hood. Delp and Singer selected models that are representative of the different types of undercabinet exhaust hoods available in the U.S. retail marketplace. Several hoods covered only part of the two front burners of the gas stove. The coverage of one hood, a premium model, extended out beyond the front burners. Some of the models had grease screens, or metal covering their bottoms, and some were open underneath. Two were ENERGY STAR-rated. The seven ranged in price from $40 for an economy model to $650, with most falling in the $250 to $350 range.

ENERGY STAR ratings for exhaust hoods only consider a hood's energy use and noise level, not its efficiency at capturing exhaust.

Their results showed that exhaust hoods varied widely in their performance, and while most of the hoods performed relatively well at venting exhaust gases, most do not do everything well—some hoods had high capture efficiencies, some were very quiet, and some were energy-efficient, but rarely were all three qualities captured in a single exhaust hood.

Hoods that achieved airflows recommended by the Home Ventilating Institute's HV1 standard showed capture efficiencies of about 80 percent or greater for back burners but only 60 percent or greater for the oven and 50 percent or greater for front burners. Open hoods had higher capture efficiency than those with grease screen- and metal-covered bottoms.

The hood with the highest capture efficiency, exceeding 80 percent for front burners, was a model with a large, open hood that covered most of the front burners, but it generated sound levels too high for normal conversation. The capture efficiency of hoods meeting ENERGY STAR criteria was less than 30 percent for front and oven burners.

"These results suggest ways that manufacturers can improve the performance of their products," says Singer. "Improving the geometry of the hoods—by making them deeper front to back and using methods such as recessed grease traps, blower entries up inside the hood, and better fans and motors—will improve their capture efficiency."

—Allan Chen

Additional information:

American Chemical Society press release [http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_ARTICLEMAIN&node_id=223&content_id=CNBP_030050&use_sec=true&sec_url_var=region1&__uuid=eb01434b-6641-4bb7-baaa-4caf8bf5cc7c]

"Performance Assessment of U.S. Residential Cooking Exhaust Hoods [http://pubs.acs.org/stoken/presspac/presspac/abs/10.1021/es3001079]," by Woody Delp and Brett Singer, is published in *Environmental Science & Technology*

This research was funded by the California Energy Commission, the U.S. Department of Energy, the U.S. Department of Housing and Urban Development, and the U.S. Environmental Protection Agency.

Help EETD Researchers Study the Effect of Cooking on Indoor Air Quality—Please Fill Out This Brief Survey

Help the Residential Building Systems Group of the Environmental Energy Technologies Division to model exposures to air pollutants in homes! Please take a few minutes and fill out our cooking survey [https://www.surveymonkey.com/s/LBNL_Cooking_Exposure].

The survey asks questions about what and how you have cooked in past 24 hours in your home. The survey does not ask for any private information and should only take 10 minutes of your time. Previous work in the Residential Building Systems Group [http://homes.lbl.gov] has shown that cooking at home is a significant source of indoor air pollution and that what and how you cook affects pollutant concentrations in your homes. The survey results will be used to develop behavior protocols for use in indoor exposure models at Lawrence Berkeley National Laboratory. This research is approved by the Lawrence Berkeley National Laboratory Human Subjects Committee.

Thank you for your time!

New Study Finds the U.S. Wind Power Market Riding a Wave That Is Likely to Crest in 2012

Facing looming policy uncertainty beyond 2012, the U.S. remained one of the fastest-growing wind power markets in the world in 2011—second only to China—according to a new report released by the U.S. Department of Energy and prepared by Lawrence Berkeley National Laboratory (Berkeley Lab). Roughly 6.8 gigawatts (GW) of new wind power capacity were connected to the U.S. grid in 2011—more than the 5.2 GW built in 2010, but below the 10 GW added in 2009. Driven by the threat of expiring federal incentives, new wind power installations are widely expected to be substantially higher in 2012 than in 2011, and perhaps even in excess of 2009's record build.

Other key findings from the U.S. Department of Energy's "2011 Wind Technologies Market Report" include:

- Wind is a credible source of new generation in the United States. Wind power comprised 32 percent of all new U.S. electric capacity additions in 2011 and represented $14 billion in new investment. Wind power currently contributes more than 10 percent of total electricity generation in six states (with two of these states above 20 percent) and now provides more than 3 percent of total U.S. electricity supply.
- In spite of the lack of policy clarity, wind turbine manufacturers and their suppliers continued to localize production domestically in 2011. As a result, a growing percentage of the equipment used in U.S. wind power projects is being sourced domestically: 67 percent in 2011, up from just 35 percent back in 2005–2006. However, Ryan Wiser, a Staff Scientist at Berkeley Lab and co-author of the report, notes, "behind these positive headline numbers, the domestic wind industry supply chain is currently facing severe pressure, due to uncertain prospects after 2012." Specifically, profit margins have been declining and concerns about manufacturing overcapacity have deepened, potentially setting the stage for significant layoffs if demand for turbines (for post-2012 delivery) does not pick up.
- Turbine scaling has boosted wind project capacity factors. Since 1998–1999, the average nameplate capacity of wind turbines installed in the United States has increased by 174 percent (to 1.97 MW in 2011), the average turbine hub height has increased by 45 percent (to 81 meters), and the average rotor diameter has increased by 86 percent (to 89 meters). This substantial scaling has pushed average capacity factors among new wind projects higher over time, though the increase has been mitigated in recent year by significant curtailment of wind energy output in some regions, along with a trend towards wind developers building out lower wind speed sites.
- Falling wind turbine prices have begun to push installed project costs lower. Wind turbine prices have fallen 20 to 30 percent from their highs back in 2008, but this decline has been slow to show up in installed project cost data, which only

began to turn the corner (on average) in 2011. Data from a preliminary sample of wind power projects being built in 2012 suggest further reductions in installed project costs.

- Lower wind turbine prices and installed project costs, along with improved capacity factors, are enabling aggressive wind power pricing. Grouping projects according to the year in which they signed a power purchase agreement (PPA) makes it clear that wind power pricing peaked among those projects that executed contracts in 2009 and has fallen substantially since. Among a sample of wind power projects with contracts signed in 2011, the capacity-weighted average levelized price is $35/MWh, down from $59/MWh for projects with contracts signed in 2010, and $72/MWh for projects with contracts signed back in 2009.
- "Wind PPA prices—particularly in the central U.S.—are now approaching previous lows set back in 2003," notes Berkeley Lab Research Scientist and report co-author Mark Bolinger. "But even with today's much lower wind energy prices, wind power still struggles to compete with depressed natural gas and wholesale power prices in many parts of the country."
- Looking ahead, projections are for continued strong growth in 2012, followed by dramatically lower but uncertain additions in 2013. With key federal incentives for wind energy (including bonus depreciation and a choice of the production tax credit, investment tax credit, or Section 1603 Treasury cash grant) currently slated to expire at the end of 2012, new capacity additions in 2012 are anticipated to substantially exceed 2011 levels—and perhaps even the record high set in 2009—as developers rush to commission projects.

At the same time, the possible expiration of these incentives at the end of 2012, in concert with continued low natural gas prices, modest electricity demand growth, and existing state policies that are not sufficient to support continued capacity additions at the levels witnessed in recent years, threatens to dramatically slow new builds in 2013 and beyond, despite recent improvements in the cost and performance of wind power technology.

—Allan Chen

Additional information:

Read the U.S. Department of Energy press release [http://energy.gov/articles/energy-report-us-wind-energy-production-and-manufacturing-surges-supporting-jobs-and].

The full report (*2011 Wind Technologies Market Report*), a presentation slide deck that summarizes the report, and an Excel workbook that contains much of the data presented in the report, can all be downloaded at the Electricity Markets and Policy website [http://eetd.lbl.gov/ea/ems/re-pubs.html].

Berkeley Lab's contributions to this report were funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

B-PATH: Quantifying the Impact of Structural Materials

A new software tool from scientists at the Lawrence Berkeley National Laboratory (Berkeley Lab) will help architects, engineers, and urban planners better assess and manage the environmental impacts of structural materials in commercial buildings.

The software tool, called the B-PATH model (Berkeley Lab Building Materials Pathways), allows designers and builders to estimate the energy, resources, and environmental impacts associated with the manufacture of structural materials; their effects on the energy use of a building during operation; and their impacts when the building is ultimately demolished and its constituent materials are reused, recycled, or disposed of. The Berkeley Lab's development of the B-PATH model was sponsored by the Portland Cement Association (PCA).

"Minimizing the environmental impacts of a building throughout its entire lifecycle is a promising way of reducing the energy use and greenhouse gas emissions of buildings," says Eric Masanet, the leader of the team that developed B-PATH. "The key is having a tool grounded in sound science to perform a lifecycle analysis—the data analysis and systems mass and energy balance modeling techniques to estimate the inputs of fuels, materials, and resources (and outputs of pollutants and waste) associated with all relevant processes in the lifecycle of a product or service."

In 2009, according to the U.S. Department of Energy, commercial buildings accounted for nearly 20 percent of U.S. primary energy use, more than one-third of U.S. electricity use, and about 15 percent of U.S. direct natural gas use. There are more than 4.6 million commercial buildings in the United States, with more than 64 billion square feet of floor space. According to a 2010 National Research Council report, the human health damages associated with the amounts of electricity and natural gas consumed by U.S. commercial buildings may be on the order of $20 billion per year.

The structure of a commercial building, such as its concrete or steel frame, uses a larger quantity of materials that require high energy per weight to manufacture than any other element of the building. A building design that uses the optimum amount of these building materials minimizes the energy required to manufacture them and helps to keep building costs down.

In the final phase of a building's lifecycle, demolition and materials removal, the B-PATH model can help determine how improved reuse and recycling can reduce the energy costs of the structural materials in new buildings. Using the correct structural materials to maximize reuse and recycling helps minimize energy use, because using recycled building materials requires less energy than manufacturing new materials.

B-PATH allows users to model the use of a range of typical structural building materials like concrete, steel, and lumber from their production, transportation, and construction until their end-of-life processes. Users can define which fuels and how much electricity is used in each of these processes, throughout the lifecycle.

The method B-PATH uses to calculate results is transparent and public, so that its users can understand how the calculations were made. Users can model variations in production pathways that occur as a result of supply-chain configurations, geographical locations of plants, plant technology vintages, fuel mixes, logistics, and other materials pathway characteristics that can be unique to local and regional supply chains. The model incorporates both current practice and best practice methods of manufacturing and construction to determine how they affect energy use. The user can tailor results to specific U.S. regions, which vary by climate, local and regional characteristics in materials supply chains, construction practices, and end-of-life pathways, as well as in the mix of fuels for electrical power supply sources and volume of water consumption.

Model results provide users with an estimate of a building materials' lifecycle energy use and greenhouse gas footprint. By modeling different scenarios, users can identify the optimal strategy to better reduce the energy use and long-term environmental effects of a commercial building before even breaking ground.

—Allan Chen

Additional information:

"*Life Cycle Evaluation of Concrete Building Construction as a Strategy for Sustainable Cities [http://energy.lbl.gov/staff/masanet/bpath.html]*," by Alexander Stadel, Petek Gursel, and Eric Masanet.

A copy of the report is also available through PCA [PDF [http://www.cement.org/DC/SN3119.pdf]].

The model is available as a download [http://energy.lbl.gov/staff/masanet/bpath.html].

Berkeley Lab and CalCEF Launch CalCharge Consortium to Support California's Battery Industry

A Berkeley Lab researcher uses a scanning electron microscope to characterize the microstructure of different materials.

In May, Lawrence Berkeley National Laboratory (Berkeley Lab) partnered with CalCEF, which creates institutions and investment vehicles for the clean energy economy, to launch CalCharge, a consortium uniting California's emerging and established battery technology companies with critical academic and government resources. The consortium will bring together dozens of California battery companies and institutions to work on applications for consumer electronics batteries, electric/hybrid vehicle transportation, and the electric grid. Berkeley Lab, CalCEF, and other Bay Area academic institutions aim to create a regional ecosystem for innovation in energy storage that will jumpstart a new era of battery technologies and help to ensure that U.S. companies succeed in this highly competitive environment.

"The next decade will be critical for this industry and this region," said Berkeley Lab Director Paul Alivisatos. "With our highly regarded battery scientists and state-of-the-art equipment at Berkeley Lab, the CalCharge consortium will be able to leverage these resources to enable the development of battery solutions for electric transportation and other clean energy applications in California."

CalCharge is a first-of-its-kind public-private partnership working to accelerate the timeline of energy storage commercialization and market adoption through technology assistance, workforce training, and market education. Members will have access to Berkeley Lab's world-class scientific facilities and personnel, including testing and diagnostics equipment not available to many start-up companies. CalCharge offers a streamlined and more affordable channel for Cooperative Research and Development Agreements (CRADAs) and similar arrangements that will help scale battery innovations from bench to market.

"To broadly scale renewable energy requires tackling the challenges of energy storage, and no technical community is better suited to those challenges than California's battery engineers and scientists," said Dan Adler, CalCEF's president. "The companies and organizations that make up CalCharge will be central to forging a renewable energy future."

California has emerged as the epicenter of U.S. battery innovation, with more than 30 startups and large companies concentrated in the Bay Area alone. The state has more battery technology patent registrations than the next three leading states combined, and in 2011 venture capital investment in energy storage grew thirteen-fold over the previous year, constituting 11 percent of the state's total VC investment in clean technology.

"There's a lot of battery know-how in California, specifically the Bay Area, but technology startups need an ecosystem to thrive," said Venkat Srinivasan, head of Berkeley Lab's energy storage research program. "The Berkeley Lab battery program, long known for its deep expertise in solving the problems in advanced batteries, is ideally positioned to work with battery companies in the region. We look forward to building this ecosystem with CalCharge."

This consortium will accelerate technology development by merging the contributions of companies involved in advanced battery technology, users of that technology, research institutions, and an educated workforce—all supported by local governments that will provide the policies and incentives to foster a regional energy storage industry.

"We wanted to start CalCharge because we know that emerging energy storage companies are facing a complex market and major technical challenges," said Doug Davenport, co-lead of the CalCharge initiative at Berkeley Lab. "CalCEF is an ideal partner for us because they bring a focus on policy and markets that truly complements our science and technology orientation."

—Julie Chao

Additional information:

CalCEF [http://www.calcef.org] is a non-profit umbrella organization that promotes the transition to a clean energy economy by creating institutions and investment vehicles that grow markets for clean energy technologies.

Please direct CalCharge membership inquiries to Doug Davenport [mailto:DTDavenport@lbl.gov].

Advanced Battery Research for Transportation [http://bestar.lbl.gov/abr/]

Batteries for Advanced Transportation Technologies [http://batt.lbl.gov/]

EETD Study for SEE Action Finds Energy Savings From Residential Behavior-Based Energy-Efficiency Programs

A new State and Local Energy Efficiency Action Network (SEE Action) report prepared by Lawrence Berkeley National Laboratory (Berkeley Lab) researchers provides guidance and recommendations on methodologies that can be used to rigorously estimate energy savings from residential behavior-based efficiency programs. The Environmental Energy Technologies Division (EETD) authors designed the report for regulators, evaluation professionals, program administrators, and other energy-efficiency program stakeholders.

Residential behavior-based energy-efficiency programs have been identified as a potential major source of new energy savings. These programs are increasingly being implemented by energy-efficiency program administrators nationwide to help meet many U.S. states' energy saving targets and requirements. They utilize strategies intended to affect consumer energy use behaviors in order to achieve energy and/or peak demand savings. They typically use one or more elements to achieve their goals, including customer outreach, energy usage feedback, competition, rewards, benchmarking, or feedback elements. Such programs may focus on changes to consumers' habitual behaviors (e.g., turning off lights), one-time behaviors (e.g., changing thermostat settings), or purchasing behaviors (e.g., buying energy-efficient appliances).

However, the widespread adoption of these programs faces obstacles, including questions about whether observed energy savings are valid and attributable to the behavior program, the savings persist over time, and the results shown for one program can be applied to another program.

"We need rigorous, objective evaluation methods for these programs," says Malcolm Woolf, Director of the Maryland Energy Administration and a leader of SEE Action for issues related to evaluation, measurement, and verification (EM+V). "Strong standards ensure that program administrators, policy makers, and regulators can be confident that the savings estimates claimed by these programs are valid."

The guidance document identifies evaluation issues and recommends methods that ensure the validity of energy saving estimates.

"We recommend using a scientific experimental design method called a randomized controlled trial," says Annika Todd, the report's lead author. "This method is the gold standard for producing valid energy savings estimates that are robust and unbiased."

Randomized controlled trials randomly assign households into two groups: one that receives the behavior-based program (the "treatment group") and one that does not (the "control group"). This method allows evaluators to determine whether any energy saved by the treatment group was due to the program, as opposed to other factors.

The report discusses methods for ensuring that the estimated savings impacts are valid and robust. Top-tier recommendations include:

- Evaluation design: use randomized controlled trials
- Avoiding potential conflicts of interest: employ an independent third-party evaluator for program evaluation, assignment of households to treatment and control groups, and data selection and analysis
- Accounting for potential double-counting of savings: use rigorous methods to account for energy savings that may be claimed by multiple programs
- Ensuring precision in estimates: achieve 5% statistical significance
- Applying impact estimates to different populations in future years: maintain a control group that is representative of all of the different participating populations for every year in which program energy estimates are being used to claim savings
- In the future, a calibrated analytic model may be created to rigorously and validly predict program savings estimates

This guidance document is especially designed for state utility regulators, who are in a position to approve utility behavior-based energy-efficiency programs. "Speaking as a regulator, we need independent, objective methods that we can turn to, and this provides exactly that," says Phyllis Reha, Commissioner for the Minnesota Public Utilities Commission and a leader of SEE Action on issues related to customer behavior and energy efficiency.

Additional information:

State and Local Energy Efficiency Action Network. 2012. *Evaluation, Measurement, and Verification of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations* *[http://behavioranalytics.lbl.gov]*. Prepared by A. Todd, E. Stuart, S. Schiller, and C. Goldman, Lawrence Berkeley National Laboratory.

SEE Action website [http://www1.eere.energy.gov/seeaction/]

LAWRENCE BERKELEY NATIONAL LABORATORY
Environmental Energy Technologies Division
NEWS

Research Highlights

Berkeley Lab and City of San Jose Partner to Boost Clean Tech in Silicon Valley

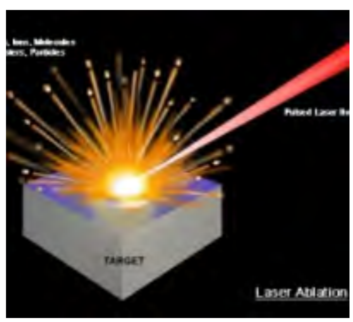
Lawrence Berkeley National Laboratory (Berkeley Lab) has partnered with the city of San Jose, California, to accelerate the advancement of clean energy technologies while helping San Jose and other cities achieve their environmental sustainability goals. The partnership brings together the extensive capabilities of San Jose's ProspeCT SV [http://www.sjeconomy.com/prospectsv.asp], a facility to showcase and validate technologies, with Berkeley Lab's focus on cutting-edge technology development and applied research.

The partnership will provide a critical linkage for clean tech companies between ProspeCT SV and the resources of Berkeley Lab, such as its technology transfer program, **FLEXLAB**, a series of building systems test beds opening in 2013, and CalCharge, a Berkeley Lab-CalCEF partnership supporting emerging battery companies in California. The **ProspeCT SV** facility will provide a space for companies to connect with private and public investors, as well as collaborate with academic and industry partners in Silicon Valley.

"A key priority for both Berkeley Lab and San Jose is to make cities more energy efficient and environmentally sustainable," said Horst Simon, deputy director of Berkeley Lab. "We see this partnership as an important way to align our research with San Jose's sustainability goals, and work together towards responding to the energy and environmental challenges of local communities."

—Julie Chao

LAMIS Wins a 2012 R&D 100 Award



Laser Ablation Molecular Isotopic Spectrometry

LAMIS, which stands for Laser Ablation Molecular Isotopic Spectrometry, has won a 2012 R&D 100 award. It was developed by a research team in the Environmental Energy Technologies Division of Lawrence Berkeley National Laboratory. The R&D 100 awards are also known as the "Oscars of Innovation."

LAMIS is a technology that could loom large in the future of homeland security and planetary space exploration. It entails focusing the energy of a high-powered laser beam to a tiny spot on the surface of a sample to create a plasma plume for analysis. Each species of atoms or ions in the plasma will emit light with signature spectral emission peaks that can be measured to identify the specific isotopes of a chemical element within. LAMIS offers a faster, less expensive, green chemistry alternative to existing mass spectrometry techniques, and it can be carried out across vast distances.

Requiring only a laser beam and an optical spectrometer to perform real-time isotopic analyses of samples at ambient pressures and temperatures, LAMIS represents what may be the only practical means of determining the geochronology of samples on Mars or other celestial bodies in the Solar System. It also has many important applications here on Earth, including nuclear forensics aimed at non-proliferation of nuclear weapons and terrorism. The LAMIS development team included Rick Russo and Xianglei Mao of Berkeley Lab's Environmental Energy Technologies Division; Osman Sorkhabi, now with the LAM Research Corporation; and Alexander Bol'shakov, now with Applied Spectra, which co-nominated LAMIS with Berkeley Lab.

Sources and Credits

Sources

Energy Efficiency & Renewable Energy's Energy Savers

These web pages [http://www.eere.energy.gov/consumer/] provide information about energy efficiency and renewable energy for your home or workplace.

DOE's Energy Information Administration (EIA)

EIA [http://www.eia.doe.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://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

Assistant Web Design
Jonathan Abel Buickerood

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. 11, No. 1 [http://eetd.lbl.gov/newsletter/nl40/], Summer 2012

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.

Readers are free to reprint or otherwise reproduce articles at no charge, with proper attribution to the *Environmental Energy Technologies Division News*.

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.

Summer Newsletter: Vol. 11, No. 1 [http://eetd.lbl.gov/newsletter/nl40/]
Environmental Energy Technologies Division News [http://eetd.lbl.gov/newsletter/]