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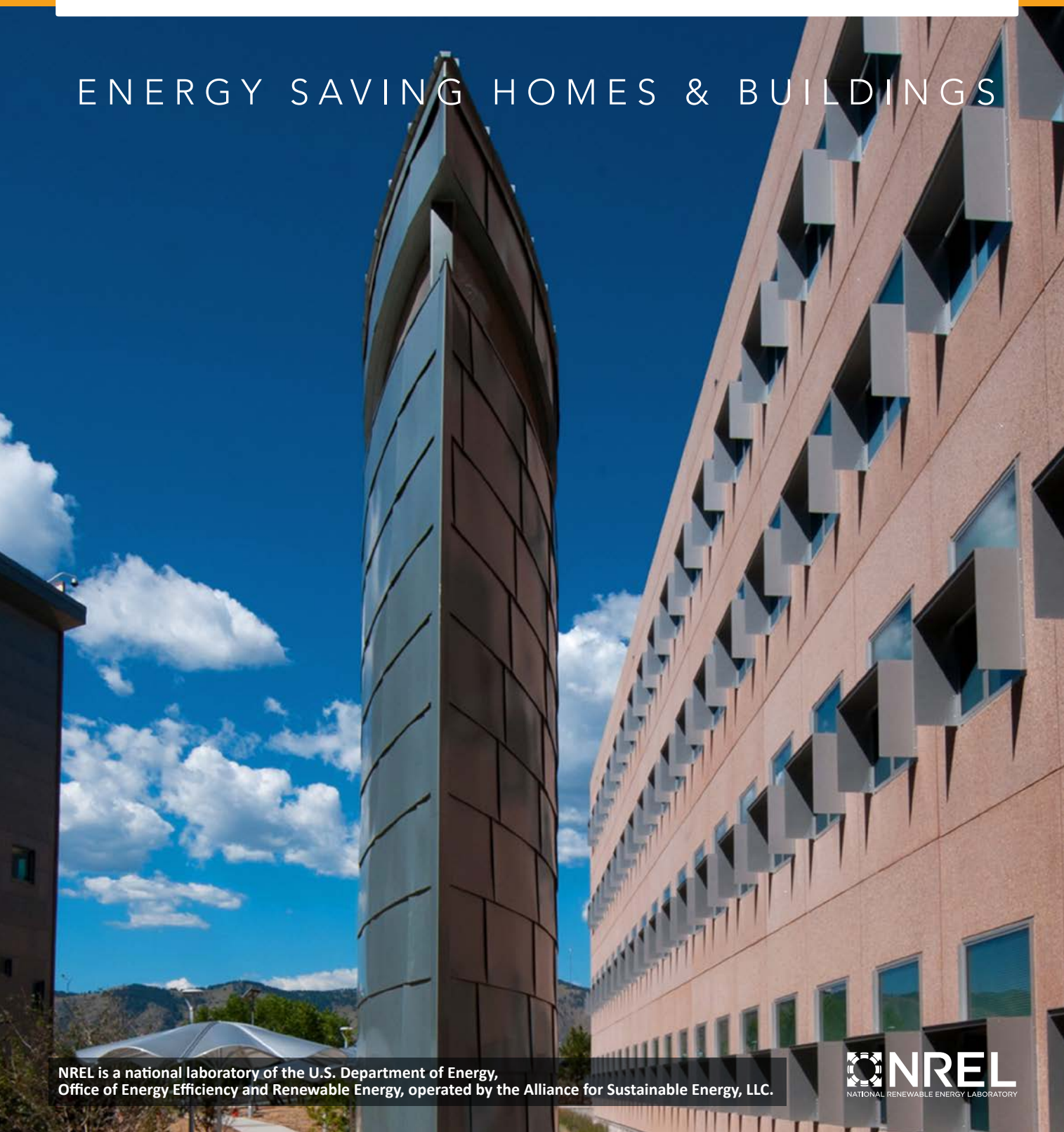
CLEAN ENERGY INNOVATION AT NREL

Continuum

ENERGY SAVING HOMES & BUILDINGS



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NREL
NATIONAL RENEWABLE ENERGY LABORATORY

DAN SAYS

ENERGY SAVING HOMES & BUILDINGS

This issue of *Continuum* focuses on the research the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) conducts to improve the energy efficiency of residential and commercial buildings. At first glance, energy efficiency may not seem as exciting as our work in harnessing renewable energy sources, but we will never accomplish our nation's goal of energy independence without addressing both the supply and demand sides of the equation.

To put the importance of energy efficient buildings in perspective, heating, cooling, and lighting our homes and commercial structures account for more than 70% of all electricity used in the United States. That costs homeowners, businesses, and government agencies more than $400 billion annually, about 40% of our nation's total energy costs. Producing that energy contributes almost 40% of our nation's carbon dioxide emissions. By 2030, an estimated 900 billion square feet of new and rebuilt construction will be developed worldwide, providing an unprecedented opportunity to create efficient, sustainable buildings—but only if we act now.

Increasing the energy performance of our homes alone could potentially eliminate up to 160 million tons of greenhouse gas emissions and lower residential energy bills by $21 billion annually by the end of the decade.

That is why improving the energy efficiency of our homes and commercial buildings is a very big, very important research challenge, and a key element of NREL's mission.

NREL's commercial and residential buildings research involves multidisciplinary teams focused on accelerating the adoption of cost-effective energy efficiency technologies and practices by architects, designers, engineers, developers, and construction companies, as well as the remodeling and building retrofit industry.

Our researchers explore energy efficiency options for both new and existing homes and commercial structures, including a holistic view of performance and the interaction of building components. In partnership with DOE, our team works with leading manufacturers, utility programs, other federal agencies, universities, and trade organizations to evaluate and deliver innovative efficiency solutions. Working on a range of building projects in the field over the past two decades, NREL has developed proven tools and resources to maximize energy savings.

In this issue of *Continuum* you will find articles describing our work with industry and government to develop standards, training, and professional certifications for home energy improvement professionals, as well as software and visualization tools to maximize commercial building energy performance. You will also learn about our field work assisting the military and local governments to reduce their building energy consumption, and innovative technologies pioneered by NREL to improve efficiency.

Through partnerships with industry and government-funded research institutions such as NREL, we are meeting the challenge of making the United States a model of energy efficiency.

Dr. Dan E. Arvizu, Laboratory Director

Cover Photo by Dennis Schroeder, NREL

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Photo by Dennis Schroeder, NREL

NREL PROVIDES A FOUNDATION

FOR HOME ENERGY PERFORMANCE

NREL-led guidelines effort enables breakthroughs for the home energy performance industry.

RAY BOWMAN was hunting a monster inside an aging ranch-style house in Thornton, Colorado—something that was gorging on energy. The trail began upstairs in the kitchen, and as homeowner Rocco Solano looked on, Bowman drew his weapons: a tape measure, combustion meters, and a master checklist. He moved with a precise confidence reflecting his experience. In 2012, he was among the first to earn the Home Energy Professionals (HEP) Certifications Energy Auditor certification which is based on collaborative work by NREL, DOE, and the home energy performance industry.

> "The HEP certification helps you understand the whole system—how things relate to each other."

Bowman, a 13-year veteran of Arapahoe County's Weatherization Division, worked methodically, analyzing smaller quarry such as the refrigerator and improperly installed outside vents. But a major nemesis to energy efficiency hulked in the basement, a fitful creature which had plagued the house.

Solano led him down creaking stairs until they came face to face with the beast—a 138,000 Btu furnace blazing away. The sight surprised Bowman, who audits homes for DOE's Weatherization Assistance Program (WAP) in both Arapahoe and Adams counties. "This looks to be about three times the size needed for this house," he said. He explained that when Arapahoe County Weatherization crews returned to make upgrades, the house would hold much of the heat it had been losing—making the furnace "cycle short," wasting more energy. "It would be like driving your car around the neighborhood with your accelerator floored," Bowman said.

Yet making one isolated fix is not the auditor's goal. During the four-hour session in December 2013, he found prey lurking in plain sight: an unreachable freezer draining electricity in the garage, hollow walls, missing insulation, and a blocked-off fireplace with a flue that had been open the entire 21 years the family lived there. By the time he conducted a Blower Door test, sealing off an entrance as a fan pulled air to simulate wind hitting

Photo by Dennis Schroeder, NREL

Ray Bowman, right, a Home Energy Professionals Certifications Energy Auditor with Arapahoe County's Weatherization Division, shows Rocco Solano, energy loss detected with an infra-red camera during an audit of Solano's Thornton, Colorado home.

the house, his impressions were confirmed. "It was even worse than I expected" as air leaked everywhere. By reporting his findings in the computerized Weatherization Assistant program—used to implement WAP—and the National Energy Audit Tool, he essentially creates a work order for weatherization crews to make the upgrades.

Certified auditors such as Bowman are trained to look at buildings holistically and not only in terms of efficiency. "The HEP certification helps you understand the whole system—how things relate to each other," he said. Safety issues such a gas leaks or improper venting are on their comprehensive checklist. The hunt for the multi-headed beast in Thornton was over, part of a quest to slash another energy bill—in this case an unacceptably high rate of nearly $400 per month for a 2,436-square-foot residence. Solano, anxious at first, was grateful. "Ray was very thorough," he said. "I hope he can tame the monster."

EVOLVING THE WEATHERIZATION MODEL

DOE's weatherization program, 35 years old in 2014, has provided retrofit services to more than 6.4 million low-income households, saving 36% of building energy use. The Recovery through Retrofit report in 2009 noted that upgrading energy performance in U.S. homes could reduce energy usage by 40% per home, cut up to 160 million metric tons of greenhouse gas emission annually by 2020, and have the potential to lop $21 billion off yearly home energy bills—with fixes paying for themselves over time.

But while there have been various energy performance standards and best practices across governmental agencies and industries, a single set of recommended retrofit guidelines had been missing in the home energy performance marketplace. That void led to a variance of verifiable outcomes in the energy upgrade industry. To remedy that, WAP, supported by the WAP National Training and Technical Assistance Plan, launched the Guidelines for Home Energy Professionals Project. The program is designed to empower the home performance industry to deliver high-quality work. It set three goals:

- Define quality work through standard work specifications;
- Define quality training through a rigorous process; and
- Offer advanced professional certifications for industry workers.

Three years ago, DOE tapped NREL to lead the project.

"NREL was chosen because of our ability to bring industry together for market transformational activities," said NREL Principal Lab Program Manager Dan Beckley. "The industry wasn't going to invest in creating resources like these in the project because it's not organized in that way."

The $11.5 million American Recovery and Reinvestment Act-funded effort led to breakthroughs, starting with the Standard Work Specifications (SWS).

Photo by Dennis Schroeder, NREL

Ray Bowman, above, a Home Energy Professionals (HEP) Certifications Energy Auditor with Arapahoe County's Weatherization Division, performs a Blower Door Test during an audit of Solano's Thornton, Colorado home.

"NREL was chosen because of our ability to bring industry together for market transformational activities."

Photo by Dennis Schroeder, NREL

NREL helped develop the Standard Work Specification and Job Task Analyses that enable weatherization work like this home insulation to be performed effectively and safely.

Photo by Dennis Schroeder, NREL

By using the NREL-developed SWS online tool, a weatherization crew leader can hand out checklists to his crews as they perform upgrades like drilling a hole to add insulation.

BUILDING CONSENSUS AND TOOLS IN THE BUILDING PERFORMANCE INDUSTRY

To kick off the effort, NREL, along with partners such as market-energy consulting firm Advanced Energy, convened groups of national single-family housing industry subject matter experts to see what the new standards would look like. "It was for industry, by industry," Beckley said. "We simply were the facilitators and provided technical expertise." NREL Project Manager Chuck Kurnik added, "The key was getting industry engaged. The fact that we reached out made it that much more impactful."

"NREL and DOE took the right path by bringing industry experts together," said Advanced Energy's Brian Coble. Building energy performance gurus from six climate zones in the country worked in three sessions to create specifications, define work, and evaluate outcomes of retrofits—an industry first. "It's easier to hit a target when you know what to shoot for," he said.

NREL made the drafts available for public comments and factored in more than 2,000 responses. "It was not something that we created in a vacuum. This had industry buy-in," Kurnik said. During the three-year development process of the SWS, NREL had more than 300 industry professionals involved.

As important as the SWS was for single-family houses, there was as much value in both manufactured housing and multi-family housing SWS documentation, each generated by their own expert groups.

"One of the main benefits of NREL's work is that it gives something specific for multi-family housing," said Nick Dirr of the Association for Energy Affordability, another NREL consulting partner. These "give a holistic understanding of a building. Some things aren't plug-and-play—they're complex. And SWS does a really good job of showing how to install upgrades in a manner that's safe, durable, and efficient."

To increase uptake and usefulness, NREL developed a new SWS online tool which was released in August 2013.

"NREL pursued a user-centered design approach to building the tool, allowing us to identify key user requirements and deliver the functionality needed to support the activities of workers in the field," said NREL Communications Project Lead Steve Lommele. "For example, one of the functionalities of the tool is that as a crew leader approaches a house, he will have a scope of work so he can hand out checklists to his crews." A "Favorites" feature allows users to identify and show details of any part of the house being worked on. That information can be emailed to mobile devices so workers have clear expectations of outcomes. NREL also developed an application programming interface that is available to the public, so companies can integrate it into tools for their employees. "SWS trains workers, helps direct what kinds of products are used, and helps assure quality. Everything flows out of this," Coble said.

OTHER QUALITY BENEFITS ADD ON TO SWS

Using the SWS as a foundation, the NREL project team and industry then developed Job Task Analyses (JTA) to reflect knowledge, skills, and abilities needed to perform a job effectively and safely. The JTAs reflect the four most common job classifications in DOE's weatherization network and the industry at large:

- **Energy Auditor**
- **Quality Control Inspector**
- **Crew Leader**
- **Retrofit Installer/Technician.**

"Defining quality work and outlining what it takes for a worker to deliver quality work has a lot of non-energy efficiency benefits," said NREL Project Coordinator Amy Hollander. "Experienced auditors know to check for gas leaks and carbon monoxide gas, ensuring the safety of building occupants. They understand building performance and can mitigate home temperature differences through zonal pressure testing to improve comfort levels." Another benefit is that companies can now refer to a document to see what's required of a job—and hold an employee accountable.

The final project component adds independent American National Standards Institute-accredited Home Energy Professional Certifications. The Building Performance Institute (BPI) was licensed as the first certifying body to oversee exam development and deliver four certifications to the marketplace that build on BPI's existing credentials in the home performance career ladder:

- **Energy Auditor**
- **Retrofit Installer**
- **Crew Leader**
- **Quality Control Inspector.**

DOE has mandated a certified Quality Control Inspector in government-funded weatherization by 2015.

Bowman is proud of his certification—one of the few in the state—and sees it as benefiting more than just him. "The education is not mine to have, but something to share—to pull my peers up to a higher level." Getting the training and having tasks broken down for home energy performance workers is a plus. "It helps improve the finished product through quantification," he said. No longer is it enough to simply add insulation. "We know insulation is crucial, but how much do you need? You see people who just put it in, but they can cover up health and safety issues. I've seen things like exposed wires hidden under insulation.

"It is important to have these checklists in your head when you do an inspection," Bowman added. He believes that the SWS and JTAs are improving the industry. He plans to seek Quality Control Inspector certification in 2014 so he can verify compliance of retrofit work performed based on work plans and standards. Across the industry, trainers can begin training others. And over time, it is likely that certifications will become valuable to workers and contractors seeking to show value to potential employers or customers.

Experts see a growing impact from all of these efforts. "My hope is that utilities increasingly see the SWS as a resource, and the basis for an energy efficiency program," Coble said. He has already seen it with utilities he consults with in the Southeast and Southwest. And with new certifications, the links between building public trust in retrofits as well as the benefits of fewer return calls for work could influence great industry acceptance. It could drive the expected boom in building energy efficiency performance.

The successful SWS and JTA effort has led to additional efforts for single family home and commercial buildings industry professionals.

—Written by Ernie Tucker

> "Some things aren't plug-and-play—they're complex. And SWS does a really good job of showing how to install upgrades in a manner that's safe, durable, and efficient."

COMPUTING ADVANCES ENABLE MORE EFFICIENT BUILDINGS

Computers, apps, and visualization tools open up new possibilities to improve the energy performance of buildings.

Computers are becoming ubiquitous devices in the United States: along with countless desktop and laptop computers Americans use at home and at work, more than half of the U.S. population now owns a smart phone, which is essentially a pocket-sized computer. These devices, in turn, open up a world of new possibilities. For instance, the ability for smart phones to use global positioning systems (GPS) to determine their location creates new opportunities for finding a nearby service and determining how to get there.

Computers are also unlocking new powerful possibilities to save energy in buildings, and NREL is at the vanguard of efforts to use design and simulation software—along with tablet computers, apps, massive data storage, and visualization tools—to improve the energy performance of buildings at every stage in their life cycle. As noted by Larry Brackney, NREL's section supervisor for commercial building controls and analysis tools, many decisions go into every stage of building design and operation, and NREL's goal is to help building professionals understand the energy implications of these decisions.

"We're creating the tools that allow architects and designers to assess the tradeoffs that they are making—whether they are aware of them or not—and to visualize and react to the data that's available to them," says Brackney.

One example of such a tool is OpenStudio, an NREL-developed software suite that makes it relatively simple to build a software model of a building and then analyze its energy performance. OpenStudio works with SketchUp, a 3-D drawing tool that architects often use to design buildings. Linking the two tools together encourages architects to analyze the energy performance of their designs before they are set in stone. But for NREL, OpenStudio is a stepping stone to more tools and even greater functionality.

Helping Design More Efficient Commercial Buildings

Consider NREL's work with Xcel Energy, for instance—a utility that operates in eight states, including Colorado, where NREL is located. The utility operates an Energy Design Assistance (EDA) program that offers incentives to companies constructing new commercial buildings or performing major renovations of existing commercial buildings. The incentives are based on how much energy the building will save compared to a building designed to meet the minimum building code requirements.

The EDA program provides energy consultants who help participating companies navigate the process by analyzing the building design, performing energy modeling, and suggesting design alternatives. But the utility struggled to ensure that its energy consultants would perform consistent and cost-effective analyses for its customers, so it turned to NREL for help.

"This is the same problem facing a number of utilities that have EDA programs around the country," says Brackney. "As building codes become more stringent, the viability of these programs is really coming into question, and incentive programs get shut down all the time."

In response, NREL devised a Web service—called the EDA Program Tracker, or EDAPT—that automates the entire process. The system uses OpenStudio software to analyze the energy performance of the building design. OpenStudio, in turn, links to the Building Component Library, an online repository of energy data on individual building components, such as lighting systems and energy conservation measures like increased wall insulation.

Drawing on the Building Component Library, the consultants can examine alternatives to the baseline building design and evaluate their effectiveness. Using the Building Component Library also helps ensure that the energy consultants all use the same assumptions, rather than applying their own "rules of thumb" to the design process.

Once the consultants are done with their analysis, EDAPT automatically generates a report that includes not only all the information that Xcel Energy requires, but also a summary of all the design measures examined by the consultant. In addition, the report flags any findings that seem to deviate significantly from expected results based on best practices. This allows the utility to assess the thoroughness and accuracy of each analysis.

For Xcel Energy, EDAPT also provides a way to monitor their program as a whole. The service provides Xcel Energy with a dashboard that shows the status of all their projects and allows them to analyze whether their EDA program is on track for its energy savings goals.

"We've created a process that reduces the time for the consultant and the time for Xcel Energy," says Brackney. "We've reduced Xcel Energy's administrative costs by at least 20% since this went live, and we've improved the quality."

The project has also gained the attention of DOE, which wants to make EDAPT available to utilities throughout the country. While that will help DOE meet national goals for energy savings, it could also provide an even more powerful tool for DOE: the ability to track EDA programs happening throughout the country.

"Just as the utility has a view of energy performance for their portfolio, DOE is going to have a higher-level dashboard they can look at to see how the country is doing," says Brackney. "Then we can get real impact metrics for our tools and know what measures are being considered, where they're being considered, which measures are not being considered, and how much are measures costing on average. So that's going to help DOE inform their investment in their whole portfolio of emerging technologies."

Such big-picture views could be critical to achieving the aggressive energy-saving goals necessary to meet the Obama

DID YOU KNOW?

MEET NREL INNOVATOR NICK LONG AND LEARN HOW HIS WORK CONTRIBUTES TO A CLEANER ENERGY FUTURE BY VISITING WWW.NREL.GOV/CONTINUUM/HOMES_BUILDINGS/COMPUTING.CFM

Administration's greenhouse gas reduction targets, which are part of a global effort to minimize the impacts of climate change.

Operating Buildings Efficiently by Putting Occupants in the Loop

Are you comfortable right now? Feeling a little cold or hot? If you're reading this in an office environment and the temperature seems a bit off, odds are you'll either get up to change the thermostat—and maybe make someone else uncomfortable—or you'll call your building energy manager and complain. But that building energy manager may have no way to judge if you're a lone complainer or an indication of a true problem with the building's comfort control.

At NREL's Research Support Facility (RSF), however, it works differently: each occupant has a desktop application, called the Building Agent, that allows them to provide immediate feedback on their satisfaction with the temperature, lighting, airflow, and noise levels in their area. Occupants can also send a text message.

"What we're trying to do is include people in the control loop," says NREL Engineer Nick Long. "We wanted to have the feedback from the people to also provide some capability of saying, 'It's too hot,' 'too cold,' maybe 'too sunny' or 'too much glare,' 'not enough air movement,' things like that. We want to have that feedback so that we can give that to the building managers in an aggregate, useful way."

The Building Agent knows where each employee is located, so all the feedback and location information goes into a database, along with data from local sensors and the building automation system, to provide a big-picture view of the RSF's energy performance. The desktop application also allows messages to be pushed out to the building occupants; in the RSF, which has operable windows, it is primarily used to tell occupants when to open and close their windows.

The Building Agent has two primary aspects: gathering data and visualizing it. To give the whole-campus view, NREL has created a Web-based dashboard that displays real-time energy usage as an analog dial, with expected ranges of energy use for the campus as a whole. For the RSF, users can drill down to a lower-level dashboard with individual dials for the energy produced by the building's solar power systems and the energy consumed by heating, cooling, mechanical devices, lighting, the data center, and plug loads—the energy used by equipment that is plugged in, like desktop computers and task lighting.

The clever part of these dials, however, is that the expected range of energy use or production changes with the hour, day, and season. The expected solar power production, for instance, is based on actual measurements of solar irradiance at the site. Other dials draw on a combination of models and historical data. Plug loads, for instance, increase in the morning as workers arrive, then tail off in the evening as workers leave for home. The dials provide real-time information for building managers.

"A lot of things can go wrong in a building like this, and some of them are not very self-evident," says Jake Gedvilas, building manager for the RSF. "Our building automation system does have alerts and alarms, but if something is operating within its parameters, we don't necessarily get alarms, even though there might be a problem.

"For solar power, in particular, the dial might show in the red, but we don't get an alarm, so that's helpful for us as a red flag: an inverter might be down or the snow might be covering the solar panels. So there's an explanation, generally, why things are not working within range."

The Building Agent tells building occupants whether they can open their windows and gives them a means to provide feedback on their comfort levels. Users can also check the building's current energy performance and respond to occasional surveys.

The benefits of the Building Agent have come to light a number of times since it has been launched. One of the visualization tools is a floor plan that shows which parts of the building are running cool and which parts are too warm. This feature proved useful during a recent winter deep freeze, when NREL had to reevaluate its night setbacks—how much the thermostats were turned down at night.

OPENSTUDIO SHINES AS A PLATFORM FOR BUILDING ENERGY MODELING

Back around the turn of the century—which wasn't that long ago—modeling a building's energy performance was a laborious process generally consigned to engineers who dealt with difficult user interfaces to model buildings.

NREL changed all that by creating the OpenStudio software platform, which made building energy modeling easier for architects. But the software platform has become much more than this, because many companies have built on it.

"OpenStudio, to me, is a platform for a potentially exponential number of tools and applications to be created from it," says Mary Werner, NREL's program manager for building technologies. "We have numerous private sector companies creating apps on the OpenStudio platform, as are we."

EDAPT and COFEE are just two examples of applications built on the OpenStudio platform, and other companies are using the software for a wide range of applications, such as building energy audits.

"We've seen an explosion in the last three years of new apps that are being developed based on OpenStudio software," says Werner. "Companies can build their user interface piece for whatever market they're trying to reach."

And as demonstrated by COFEE, the OpenStudio platform really shows its power when modeling a large number of buildings automatically.

"The power of OpenStudio is that we're no longer thinking of a building at a time," says Werner "Now we have the capability of doing it at scale."

"We did learn a few lessons from that," says Gedvilas. "There were a couple of areas that had night setbacks that were too low. Night setbacks help to save energy, but the building could never catch up during the day; it was just too darn cold outside, and some rooms never achieved the comfort range. So we had to make some tweaks and adjustments. But we never got any alerts on that because it was operating as programmed and designed."

There are many such anecdotes at the RSF, and to Long, this is the sound of success.

"With Building Agent, we're trying to enhance the communication between the building and the occupant and the occupant and the building; trying to connect those two together to give the facility managers a way to save energy, to look at their energy consumption and see where the issues are," says Long.

Analyzing the Energy Use of Massive Numbers of Existing Buildings

So far, we've seen how NREL is helping utilities work with their customers to design and build more efficient buildings—an effort that is slated to go nationwide—and we've seen how NREL is helping building energy managers work with occupants to operate a building more efficiently while maintaining comfort. But what about all those inefficient buildings out there? How can we identify the buildings that waste the most energy in any one area?

That's the question that National Grid, a utility that operates in the Northeast, brought to NREL. And the utility wanted to go big: it wanted to analyze the energy performance of every building in its service area—that's 20 million buildings!

"After we picked up our jaws off the floor, we sat down and thought about it and said, 'Yeah, we could figure out how to do this with OpenStudio'," says Brackney.

The result is a program called Customer Optimization for Energy Efficiency, or COFEE for short. NREL started by mining National Grid's customer data for building location, type, and floor space for each of its customers. Using Google imagery to determine the area covered by each building, COFEE makes assumptions about the building and automatically generates a baseline model of the building.

"So we have kind of an OpenStudio-based expert system that makes its best guess at what that building model might look like," says Brackney.

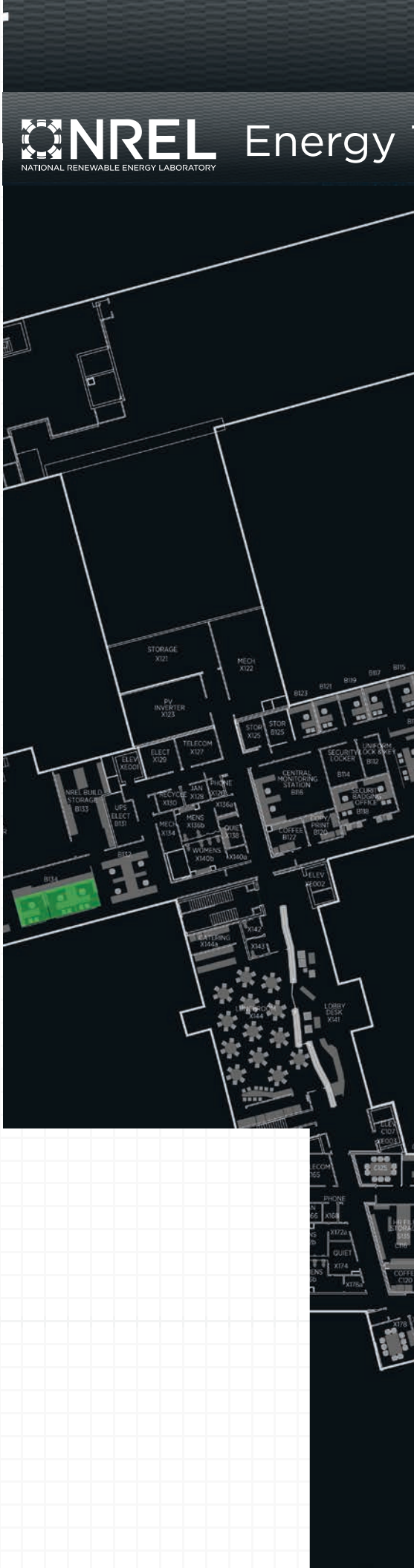
The model is then tweaked to make it fit the billing data for that location, and COFEE compares the model to National Grid's incentive programs and creates a customized sales plan for each customer. The plan may include a few questions for the customer, but once those questions are answered, the program is able to determine which energy-saving improvements are appropriate, what incentives are available, and what the payback period is for investing in the improvements.

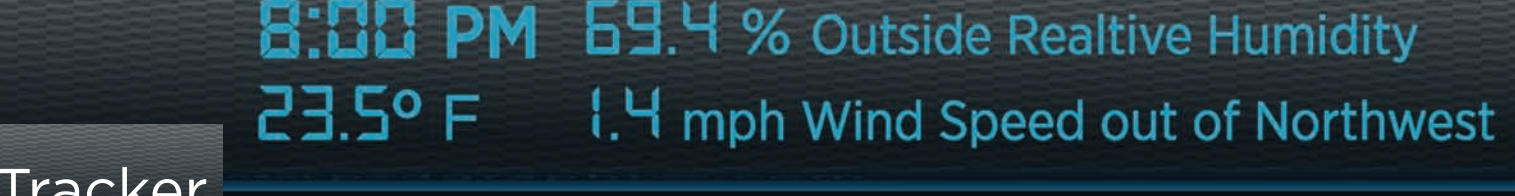
The approach minimizes the marketing outlay for the utility because it can focus its marketing efforts for its incentive programs on those customers most likely to benefit. It also maximizes the likelihood that the utility will get the benefit it aims to achieve. Looking further out, having energy models for all of the buildings in its service area could allow the utility to generate detailed forecasts of its energy demand. And although COFEE was created for National Grid, NREL and DOE hope to make it available to other utilities.

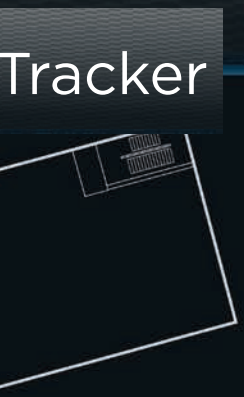
"AFTER WE PICKED UP OUR JAWS OFF THE FLOOR, WE SAT DOWN AND THOUGHT ABOUT IT AND SAID, 'YEAH, WE COULD FIGURE OUT HOW TO DO THIS WITH OPENSTUDIO'."

These examples of the design, operation, and retrofit of buildings all demonstrate a key aspect of the NREL philosophy: to try to have nationwide or even global impacts from relatively small-scale efforts. EDAPT was built to help design efficient buildings for one utility, but it may be adopted nationwide; Building Agent was built for the NREL campus, but it is available for licensing and can be applied to any large building or campus; and COFEE offers a large-scale approach to analyzing the energy performance of buildings. All of these efforts will lead to more efficient buildings throughout the United States and perhaps the world.

—Written by Kevin Eber



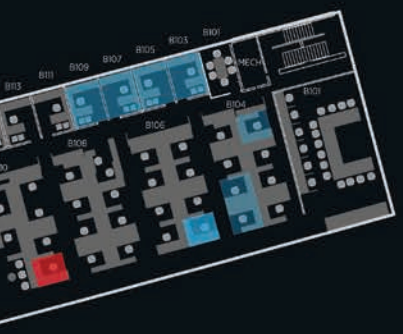


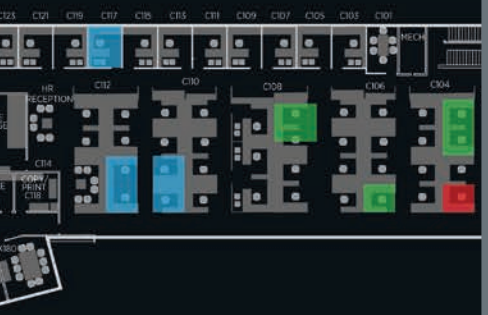


1st Floor Reports Recieved For Day

	Too Hot	Too Cold	OK
Reports	2	20	12
Distinct Users	2	16	12

Image from NREL





The Building Agent gathers occupant feedback on comfort for use by the building's energy manager and others. This image shows average responses in several areas on a cold winter day.

CREATING AN ENERGY PERFORMANCE LIBRARY WITH THE TECHNOLOGY PERFORMANCE EXCHANGE

Have you visited a hardware store lately? For most energy efficiency items, the choices can be staggering! Just try perusing today's selections of light bulbs, for instance. Professionals have the same problem as consumers. They can't buy every new product, nor can they take the time to download all the manufacturer's specification sheets and study them. They need a simpler way to access this information.

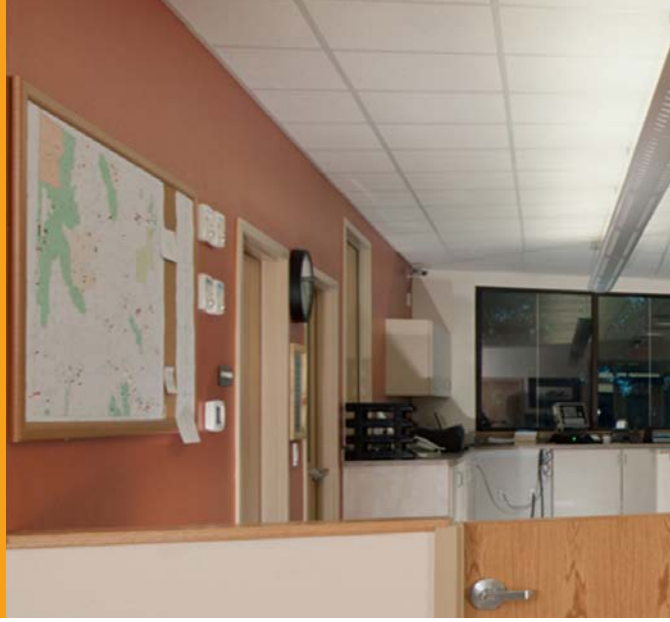
NREL has a software solution to this problem—the Technology Performance Exchange (TPEx). The TPEx is a centralized, Web-based portal for finding and sharing energy performance data for commercial building technologies. The TPEx works on a voluntary basis, allowing individuals who manufacture, supply, test, or evaluate technologies to upload product-specific energy performance data in a standardized way. One key to the approach is allowing multiple entries for each product.

"You're able to gather this performance information for specific products and compare them," says Brackney, "and it's not just a single data point; it's like 10 or 20 or 100 different descriptions of that product's performance, so you start to get a statistically significant collection of data that describes how a particular product performs."

The end result? A catalogue of sorts that can be accessed by anyone needing energy performance data.

"The TPEx allows users to search for technologies, compare detailed energy performance data, and provides the information necessary for end users to evaluate the site-specific energy and cost savings from implementing those technologies," says Bill Livingood, group manager for Commercial Buildings Research at NREL. "Subject categories range from lamps to heating and cooling systems to solar modules, with plans for more categories in the future."

ENERGY EFFICIENT WINDOW COATINGS THAT PLEASE THE EYE



NREL PARTNERSHIPS EXPAND MARKET REACH AND PROVIDE MORE ENERGY SAVING OPTIONS.

Start with a novel concept. Pursue related fundamental research. License intellectual property to companies. Understand technical barriers to greater market penetration of the technology. Partner with companies to overcome these barriers. Help a successful industry develop as a result and provide end-users with more options to choose from to save energy and gain other desired benefits. NREL has a long track record of following this path in the field of dynamic windows—windows with glass that changes properties based on environmental and user demands to improve the energy efficiency and aesthetics of buildings.

FROM GREAT IDEA TO NEXT-GENERATION MATERIALS

In 1973, even before coming to NREL, Satyen Deb conceived of making a window that incorporated tungsten oxide thin films that had adjustable properties. Once at NREL (then, the Solar Energy Research Institute), he and his colleagues continued to pursue this technology as a device that changes color when voltage is applied—an "electrochromic" device—thus controlling the amount of light and heat transmitted through it.

Since the 1990s, NREL has obtained patents on key aspects of electrochromic materials, devices, and processes, and has made this intellectual property available for licensing. Various companies have entered into development partnerships and/or license agreements to explore and capitalize on NREL electrochromic innovations: SAGE Electrochromics, Inc.; Eclipse Energy Systems, Inc.; e-Chromic Technologies, Inc.; as well as for hydrogen sensor (Nuclear Filter Technology) applications.

NREL Senior Scientist Chaiwat Engtrakul, who currently conducts research in electrochromic materials, explains, "NREL and SAGE are working together to develop innovative nanocomposites that can be used in new window designs. These next-generation materials are enabling window features desired by designers and consumers and will help grow the market penetration of this technology."

One feature that will bolster market acceptance relates to aesthetics: most architects and building occupants would prefer clear windows on one extreme and dark gray glass on the other. Addressing this preference, the SAGE electrochromic coatings have no perceptible tinting in the clear state and, when combined with the standard tungsten oxide electrochromic layer, have the potential to result in the desired dark gray.

"NREL and SAGE are working together to develop innovative nanocomposites that can be used in new window designs."

Another feature relates to performance, namely, the length of time it takes to switch between the clear and darkened states. The device switching speed depends on the ambient temperature and the area of the glass. NREL and SAGE are researching electrochromic materials that exhibit increasingly fast switching rates that consumers find desirable.

Photo from Sage Electrochromics

The dynamic electrochromic windows in this office can darken in the upper portion to block unwanted light, glare, and heat while the lower portion remains clear.

SAVING ENERGY, HELPING COMPANIES AND CONSUMERS

Neil Sbar, vice president of Energy and Technology Applications at SAGE, concludes, "We're confident that the next-generation materials being conceived through our research and development will boost the penetration of dynamic window applications within the buildings market. The ultimate impact will be a substantial decrease in energy usage over existing window technologies."

In other electrochromic research, NREL scientists are exploring avenues for retrofitting these coatings to existing glass windows. This ability would expand the options available to remodelers for the almost 20 billion square feet of windows currently installed in U.S. commercial and residential buildings.

NREL's seminal and ongoing work in dynamic window technologies, including key collaborations with industry partners, exemplifies how a national laboratory can serve as a valuable resource to companies needing to overcome technical market barriers to bring new energy technology options to consumers.

—Written by Don Gwinner

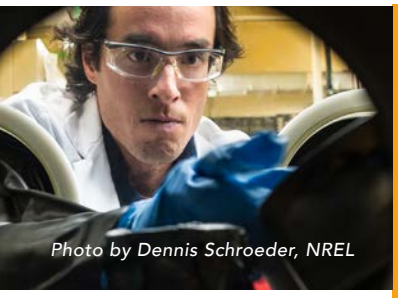


Photo by Dennis Schroeder, NREL

Reaching into a sputter deposition system, NREL scientist Chaiwat Engtrakul prepares a sample for deposition of an electrochromic film being studied in his research on next-generation materials for dynamic windows.

ELECTROCHROMICS: WHAT IT IS, WHAT IT DOES

Making a nanocomposite. NREL has worked with industry to develop a nanocomposite counterelectrode coating that surpasses state-of-the-art electrochromic coatings. A typical electrochromic coating is deposited on window glass and consists of five layers totaling about one micrometer thick, with transparent contact layers bookending a counterelectrode layer, ion-conducting layer, and electrochromic layer.

Low voltage applied across the stacked layers causes lithium ions to migrate out of the counterelectrode, initiating a solid-state process that tints the coating, darkening the glass. Reversing the voltage polarity reverses the lithium-ion flow, decreasing the glass tint and allowing more light to be transmitted through the window.

Controlling light and heat. Clear glass maximizes the entry of natural light into interior spaces, reducing the need for electric lighting. But at certain times, we may want darker glass to block some or most light—to reduce glare, prevent fading of carpets, or provide greater privacy. And in cold weather, we want windows to allow most solar energy to enter the building's interior to provide heat, whereas in warmer weather, we want to block the heat. This strategy reduces the load on the building's heating and cooling systems—less additional heating in the winter and less cooling required in the summer—to maintain occupant comfort while spending less money on energy.

NET-ZERO BUILDING TECHNOLOGIES CREATE SUBSTANTIAL ENERGY SAVINGS

Shanti Pless (right) discusses net-zero energy building methodologies and technologies during a tour of the RSF's rooftop PV system
Photo by Dennis Schroeder, NREL

RESEARCHERS WORK TO PACKAGE AND SHARE STEP-BY-STEP INFORMATION FOR DECISION MAKING AROUND NET-ZERO ENERGY BUILDING TECHNOLOGIES.

The past three decades have seen numerous energy-saving innovations in commercial building technologies, including improved insulation, windows, and heating and cooling systems. Despite these strides, energy use by commercial buildings continues to grow faster than the development and deployment of energy efficiency technologies.

By 2030, up to 135 billion square feet of new and rebuilt buildings will be constructed in the United States, representing an increase of approximately 50% in our building floor area. NREL Commercial Buildings researchers are working hard to ensure that this new building space will be highly energy efficient.

"To really have an impact, you have to start thinking about a system of net-zero energy buildings where buildings produce as much energy as they consume," said Paul Torcellini, principal engineer for NREL's Commercial Buildings Research Group.

PATH TO NET ZERO SURPRISINGLY ACCESSIBLE

To achieve net-zero energy, a building team first reduces energy use as much as possible using low-energy building technologies such as daylighting and high-efficiency heating, ventilation, and air conditioning measures, including natural ventilation and evaporative cooling. Next, to account for planned energy use, the building team focuses on planning for and utilizing sufficient renewable energy sources like photovoltaics, solar hot water, and wind power.

Renewable energy sources located on the building site are preferred, but builders also utilize resources such as biomass, ethanol, or biodiesel that can be imported or purchase off-site renewable energy sources like utility-based wind.

Motivations to realize net-zero energy use can range from federal mandates to environmental and financial considerations. An executive order signed by President Obama in 2009 calls for new federal buildings to be designed to net-zero energy standards by 2020 and operating as net zero by 2030.

Currently only an estimated 1% of commercial buildings are built to net-zero energy criteria. One reason for this small number, according to NREL's researchers, is the diffuse nature of the commercial buildings sector, which makes it difficult for new research to reach and impact the buildings market. As a result, many practitioners in the commercial buildings sector remain unaware of the accessibility of net-zero annual

energy design, assuming that it is too expensive.

In reality, NREL's commercial buildings researchers are already utilizing technologies and methodologies that achieve zero energy at little to no additional cost when compared with traditional building methods. NREL's 360,000-square-foot net-zero energy RSF cost $259 per square foot to build, compared with $250-$350 per square foot for a traditional building.

"There's a huge gap between what people think is achievable and what is actually achievable," said Torcellini.

To address this knowledge gap, NREL's researchers are paying close attention to behavioral aspects of the commercial buildings sector, examining the many factors that go into owners' and operators' decision making, from design through operations. Researchers are also working to more effectively communicate information about utilizing net-zero energy building methodologies and technologies. Conveying that net-zero energy buildings are achievable today is a top priority, said Torcellini.

DETAILED, INNOVATIVE PROCESS HELPS PAVE PATH FORWARD

One of the processes pioneered by NREL's commercial group and DOE is energy-performance-based acquisition, which building owners and designers can use to incorporate energy performance goals, language, and incentives into the planning, design, construction, and operation of a building. Recently NREL's researchers worked to incorporate all of their presentations, reports, how-to guides, and other resources into a performance-based acquisition collection featured in DOE's Commercial Buildings Resource Database.

"We're working to condense what we did here at the RSF into something that is accessible to really give people information they can use at the point of decision making," said Jennifer Scheib, an engineer with NREL's Commercial Buildings Research Group.

NREL's collection of resources provides detailed step-by-step information for each part of the performance-based acquisition process, and additional work is underway to develop guidance that will help building owners and operators address and mitigate operational risks. This information will provide needed long-term support for building teams.

"Net-zero energy is an operating goal and not just a day-one goal," said Scheib. "We want to make sure that a building is still operating at net-zero energy in year 20 of that building's life."

THE FUTURE OF NET ZERO

Although net-zero energy is currently being applied mostly to instances of new commercial construction, the concept is likely to take a much broader hold in commercial retrofits as well over the next five years, predicts Shanti Pless, a manager within the Commercial Buildings Research Group. Recently, NREL worked with the General Services Administration to document the lessons learned in attempting to achieve net-zero energy in a retrofit of the Wayne Aspinall Federal Building and U.S. Courthouse, a historic building in Grand Junction, Colorado.

Pless also expects the net-zero energy standard to become a much bigger market differentiator in the near future, with the concept taking hold in schools, banks, office space, and many other areas. He expects to see more voluntary energy codes around net-zero energy and the expansion of the concept to larger scales, such as city campuses.

"Providing information on budget-conscious net-zero energy best practices like NREL is doing is a key part of helping the industry move forward," Pless said.

"Extra cost is often a justification to not be efficient," said Pless. "There are plenty of ways buildings waste energy and money, but good energy efficient design doesn't need to."

NREL continues to pioneer work on controlling plug loads, using energy modeling tools to set energy use budgets, and challenging large building portfolio owners to achieve energy savings within their cost models, among many other areas. With this work and continued efforts focused on communicating information and influencing decision making, the net-zero energy future looks bright, with the paradigm shift NREL's Torcellini seeks on the horizon.

"Consumers should expect nothing less than net-zero energy buildings," said Torcellini. "Consumers should demand excellence out of their design teams and construction contractors."

—Written by Emily Laidlaw

BUILDING BETTER:
ADVANCED ENERGY DESIGN GUIDES

WHEN NATIONAL LABS AND PARTNERING ORGANIZATIONS EMPOWER THE COMMERCIAL BUILDING INDUSTRY WITH HOW-TO GUIDES FOR ENERGY SAVINGS, THE IMPACT IS CLEAR.

After one of the strongest tornados on record hit Greensburg, Kansas, in the spring of 2007, 90% of the small rural community was destroyed. When it came time to assess the viability of the town after the fact, citizens focused not on the damage but on their vision of a "green" Greensburg, where the homes and businesses would be built far above standard. To make it official, local representatives wrote an ordinance requiring all public buildings in Greensburg be constructed to meet Leadership in Energy and Environmental Design (LEED) Platinum ratings from the U.S. Green Buildings Council (USGBC).

But before any structure can achieve a LEED designation, the design needs to incorporate a number of recommendations for achieving energy savings over the minimum code requirements. With the guidance of the Advanced Energy Design Guides (AEDGs), Greensburg constructed nine LEED Platinum commercial buildings, each using half or less of the energy of a standard building of its type.

ASHRAE/IES STANDARD 90.1 HAS SERVED AS THE BENCHMARK FOR THE ENERGY EFFICIENT DESIGN OF BUILDINGS SINCE ITS INCEPTION IN 1975.

The 30% Advanced Energy Design Guide (AEDG) series was used as a starting point for many of the projects in Greensburg, including the USD 422 Greensburg K-12 School. The AEDGs provide building type and climate-zone-specific recommendations to help achieve 30% energy savings relative to a code-compliant building.

Photo by Lynn Billman, NREL

Photo by Dennis Schroeder, NREL

Kiowa County Memorial Hospital administrator, Mary Sweet, leads a tour of the LEED Platinum hospital in Greensburg, Kansas. Greensburg has nine LEED Platinum buildings, each using half or less of the energy of standard building of its type.

IN THE BEGINNING

ASHRAE/IES Standard 90.1 has served as the benchmark for the energy efficient design of buildings since its inception in 1975. This code represents the baseline performance standard for new construction in the United States with the exception of low-rise residential buildings.

In 2002, Don Colliver, serving as the president for ASHRAE, called for the development of documents that identify excellent building practices in addition to minimum requirements. Four organizations—ASHRAE, the American Institute of Architects, the Illuminating Engineering Society of North America, and the USGBC—formed the AEDG steering committee to realize this vision. With DOE acting as an ex-officio member of the committee and a major funding partner, this group became the driving force behind the development of user-friendly recommendations that go beyond code to achieve 30% energy savings compared to Standard 90.1-1999, and later, 50% savings over 90.1-2004.

LAYING THE FOUNDATION

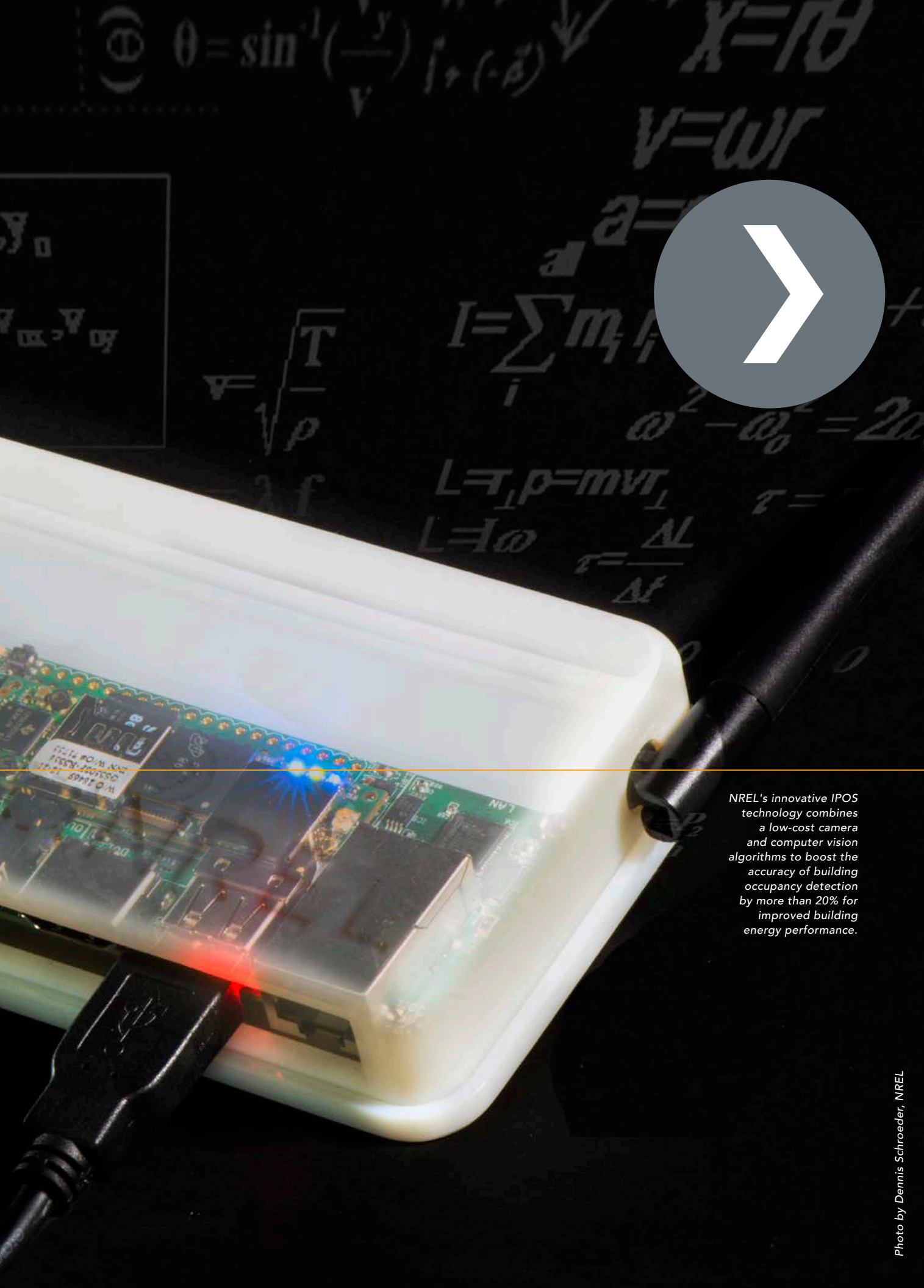
Two DOE national laboratories—NREL and Pacific Northwest National Laboratory (PNNL)—were brought in to provide robust energy modeling and life-cycle cost optimization capabilities. In addition, principal investigators from NREL and PNNL have served as the chair for the project committee, developing each guide in all cases but one.

Ten AEDGs have been produced to date, including six 30% guides and four 50% guides, which offer prescriptive approaches for achieving energy efficiency in newly constructed highway lodging, K-12 schools, small healthcare and hospitals, and commercial buildings like offices, retail locations, and warehouses. And they are being put to good use. In fact, the USD 422 Greensburg K-12 School was so successful in implementing energy efficient measures that it was selected as a case study for the AEDG for K-12 School Buildings: Achieving 50% Energy Savings Toward a Net Zero Energy Building.

More than 200,000 energy model runs are needed to develop a single guide. NREL and PNNL researchers use simulation tools such as EnergyPlus and OpenStudio to analyze a wide variety of possible directions, such as new low-energy technologies. They narrow the results down to an optimal set of measures for each building type within 16 representative climate zones.

SPREADING THE WORD

As of December 2013, more than 500,000 copies of the AEDGs have been downloaded from the ASHRAE website and distributed to building industry professionals. After hitting the half-million circulation mark, Colliver characterized the success of the AEDGs as "a dream come true," and he's right.



NREL's innovative IPOS technology combines a low-cost camera and computer vision algorithms to boost the accuracy of building occupancy detection by more than 20% for improved building energy performance.

Photo by Dennis Schroeder, NREL

SMART OCCUPANCY

SENSOR DEBUTS

NREL'S R&D 100 AWARD-WINNING OCCUPANCY SENSOR OFFERS A LOW-COST, HIGH-IMPACT SOLUTION TO A PRESSING MARKET CHALLENGE: IMPROVING BUILDING ENERGY PERFORMANCE.

Noted as one of the 100 most significant innovations of 2013 by *R&D Magazine,* the Image Processing Occupancy Sensor (IPOS) developed at NREL provides a groundbreaking solution to the challenge of improving building energy performance.

Commercial buildings and industrial plants account for roughly 50% of U.S. energy consumption, which translates to roughly $400 billion in energy costs—and a substantial portion of the carbon emissions that contribute to climate change. According to DOE, meeting President Obama's Better Buildings Challenge goal of reducing the energy intensity of all U.S. commercial buildings and industrial facilities just 2.5% annually would result in an annual savings of more than $80 billion after a decade while significantly reducing the collective carbon footprint of those facilities.

BOOSTING OCCUPANCY SENSOR EFFECTIVENESS

Occupancy sensors are one tactic for cutting building energy waste, but until now their effectiveness has been limited. With its novel approach to occupancy detection, the IPOS boosts accuracy more than 20% while providing a richer set of information for increasing building energy efficiency. That represents billions in potential energy cost savings.

For 30 years, occupancy sensors relied primarily on passive infrared (PIR) technology to infer the presence of people by detecting motion. This limited their range and accuracy, explained Senior Engineer Luigi Gentile Polese, one of the three-man team at NREL that developed the IPOS. False positives and negatives caused annoyances, such as lights shutting off when employees were working late. This often led people to disable the sensors, negating their energy-saving benefits.

To address these limitations, NREL tapped its Commercial Buildings Research Group's deep expertise in building energy efficiency and software development to create an innovative approach to occupancy detection. Polese, along with Larry Brackney and Alex Swindler, began exploring the use of computer vision in occupancy sensors. Leveraging the low-cost camera and microprocessing technologies used in smartphones, they combined image processing capabilities with computer software to develop the IPOS. Initially funded by DOE, the team later partnered with Bonneville Power Administration to make the solution even more robust.

PROVERBIAL EYE IN THE SKY

Relying on digital images, the IPOS can detect occupancy with 99% accuracy across a much wider area than PIR sensors, Polese said. Furthermore, it can segment that area into as many as 16 virtual zones and identify the number of people, the level of activity, and the amount of light in each. All of this allows for highly targeted control of lighting, heating, and other building systems based on occupant need.

"The ability to extract a rich set of feedback from a single device creates unprecedented potential to cut energy costs," said Ty Ferretti, a licensing executive in NREL's Commercialization and Technology Transfer Office. As a result, he said, the IPOS has captured the attention of some major industry players and brought a number of potential licensees to the table.

The level of interest has been "through the roof," said Ferretti, who nominated the IPOS for the R&D 100 Award. "The market is just itching for it. Everybody needs to save money, and in any business, energy efficiency is the low-hanging fruit." And the IPOS offers big bang for the buck, he said. "This is a simple, low-cost technology that can replace existing sensors and deliver substantial savings with added functionality."

"The market is just itching for it. Everybody needs to save money, and in any business, energy efficiency is the low-hanging fruit."

Image from NREL

Unlike conventional passive infrared motion sensors used to infer occupancy, IPOS uses sequential image subtractions like this one for extracting and analyzing motion-dependent occupancy content.

CUTTING ENERGY USE, COSTS

The inherent flexibility of the IPOS creates ample opportunities for customization, Ferretti said. One example is the ability to integrate the software into existing building security systems, further increasing potential capital savings. Other applications under consideration include elevator operations, medical sterilization, retail video displays, energy performance metering, and more.

In each case, the IPOS offers a low-cost, high-impact way to cut building energy waste with a relatively low up-front capital investment. And the return on that investment extends beyond corporate balance sheets to the larger U.S. goal of reducing carbon pollution in support of the President's Climate Action Plan.

—Written by Karen Petersen

Efficiency upgrades in eight active-duty Navy officer homes are projected to save $120,000 over the next 10 years, or $15,000 per home.

Photo from U.S. Navy

ENERGY EFFICIENT

DEMONSTRATION PROVES POWERFUL IN HOME RETROFITS

NREL RECOMMENDATIONS DEMONSTRATE SUBSTANTIAL SAVINGS FOR THE NAVY.

When Navy officials handed NREL a tough assignment, two NREL building engineers headed to Guam—hot, humid, and beautiful, where homes are built to handle typhoons and potential cyclones.

Residential building engineers Lieko Earle and Bethany Sparn needed to identify the most cost-effective ways to retrofit homes in more energy efficient ways.

With aggressive goals to reduce facility energy use by 37.5% from 2003 to 2020 and ensure that 50% of Navy and Marine Corps installations are net-zero energy, the Department of Defense (DoD) wanted to quickly reduce electricity use in military housing.

GO BIG OR GO HOME

"When offered the opportunity, Lieko and Bethany chose to 'go big or go home,' suggesting comprehensive retrofits rather than a more incremental approach," said Jeff Dominick, NREL principal investigator of the Navy project. "Lieko and Bethany wrote a compelling demonstration proposal and assembled a project team that included key Navy stakeholders at the regional and Naval Base Guam installation levels."

The duo had to move quickly to apply their residential buildings research experience. Their team had roughly a year to choose representative homes, install various technologies, gather data before and after the retrofits, and provide recommendations based on their results. The focus was to reduce loads related to water heating and whole-house cooling. In late 2012, the demonstration site selected was Naval Base Guam in Apra Harbor, which has 1,369 houses for its active-duty Navy and family members.

"Typically when we evaluate a home, we look at all the possible changes," said Earle. "With this retrofit, the process was simplified because we couldn't alter the concrete construction of the buildings, so the list of things we could consider was more limited."

Photo from U.S. Navy

SMALL-SCALE DEMONSTRATION, LARGE RETURN

The team employed a building energy simulation tool developed at NREL, called Building Energy Optimization (BEopt) with EnergyPlus, to identify the most cost-effective packages to increase whole-house energy efficiency. Eight homes were selected to participate in the demonstration, and based on the analysis, the technologies installed included high-efficiency air conditioners and air handlers, internet-connected programmable thermostats, low-flow shower heads, and heat pump water heaters. A few homes also got in-line dehumidifiers.

"In all eight homes, electricity use was monitored at the end use before and after the retrofits to measure differences in daily energy consumption," said Sparn. "Results showed that these technologies have the potential to save the Navy millions."

"SINCE THE NAVY PAYS THE RESIDENTIAL ELECTRICITY BILLS FOR ITS HOUSING, THIS COULD SAVE THE NAVY LOTS OF MONEY AND IMPROVE ITS CARBON FOOTPRINT."

Given Naval Base Guam's high electricity rates of $0.50 per kilowatt hour, the efficiency upgrades in the eight homes are projected to save $120,000 over the next 10 years, or $15,000 per home. With this net savings, the projected payback is less than 3 years. The biggest savings relate to the air conditioning units and replacing electric water heaters with heat pump water heaters.

"The Navy has adopted the higher efficiency water heating and space cooling technologies for its future procurements," said NREL Project Manager Gene Holland. "Since the Navy pays the residential electricity bills for its housing, this could save the Navy lots of money and improve its carbon footprint."

New air conditioning units are replaced in each house at Naval Base Guam every eight years. With 288 units replaced last year alone, this potentially equates to more than $4 million in savings over the next 10 years.

This NREL project is one of eight demonstrations supporting DoD in Hawaii and Guam that are focused in three categories: energy efficiency, renewable energy, and energy systems integration.

BENEFITS BEYOND THE NAVY

Earle and Sparn's team success may offer benefits beyond the Navy. Heat pump water heaters have not yet been widely adopted on Guam, and NREL's Guam-based contractor team now has hands-on experience with the technology. In addition, both NREL and the Navy are members of the Government of Guam Energy Task Force. Results will be shared with other members of the task force, accelerating the adoption of these commercially available technologies.

—Written by Linh Truong

Continuum

CLEAN ENERGY INNOVATION AT NREL

Continuum is NREL's publication that showcases the laboratory's latest and most impactful clean energy innovations and the researchers and unique facilities that make it all happen.

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As the only U.S. national laboratory singularly focused on advancing renewable energy and energy efficiency, NREL's mission spans the spectrum of clean energy solutions—including pioneering research in solar, wind, biomass, hydrogen, and geothermal energy. With 35 years of successful innovation from fundamental research and analysis through commercializing and deploying energy efficiency and renewable energy solutions, NREL continues to pave the way toward clean energy transformation.

Photo by Dennis Schroeder, NREL

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A CLOSER LOOK

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