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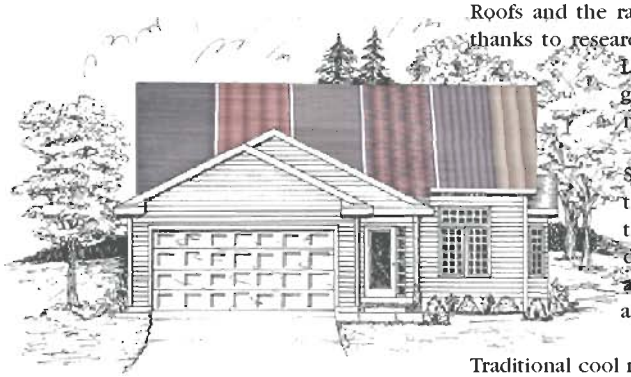
NEWS

ADVANCED ENERGY TECHNOLOGIES | ATMOSPHERIC SCIENCES | BUILDING TECHNOLOGIES | ENERGY ANALYSIS | INDOOR ENVIRONMENT

Cool Colors Project: Improved Materials for Cooler Roofs



Roofs and the rainbow of colors used in roofing materials are getting cooler and cooler, thanks to research by scientists in the Lawrence Berkeley National Laboratory (Berkeley Lab) Environmental Energy Technologies Division (EETD). The cooler roofs get, the more energy and money they save. A new research program in cool materials is developing the first cool shingle for residential roofs.

Since the mid 1980s, EETD researchers have studied the effects of increasing the solar reflectance of roofs. "Cool" roofs reflect more of the sun's radiation than do conventional roofs, lowering temperatures inside buildings, decreasing air-conditioning energy use, and reducing the "urban heat island," an elevation of air temperatures in urban areas relative to surrounding rural areas.

Traditional cool roofs are white because light surfaces absorb less solar radiation than dark ones. EETD research has demonstrated that raising the solar reflectance of a roof from about 20 percent (dark gray) to about 55 percent (weathered white) can reduce a building's cooling energy use by 20 percent. Although white materials may find acceptance on flat-roofed commercial buildings, U.S. homeowners typically demand non-white roofs for aesthetic reasons. EETD researchers, working with industry, have found that non-white cool roofs can be manufactured using colorants (pigments) that reflect the invisible, "near-infrared" radiation that accounts for more than half of the energy in sunlight. "Our research estimates that the potential net energy savings in the U.S. achievable by applying white roofs to commercial buildings and cool colored roofs to houses is valued at more than $750 million per year," says Hashem Akbari, head of the Heat Island Group at Berkeley Lab.

The group's research has shown that widespread regional application of cool roofs can reduce ambient air temperatures and retard smog formation. Cool roofs can also reduce peak electricity demand in summer, which helps reduce strain on the aging electricity grid when relief is most needed. The lower temperatures of cool roofs may also increase the roofs' serviceable lives, according to some preliminary research by the group.

Because of the recent work of Akbari's research group, the roofing industry has adopted voluntary standards for measuring the solar reflectance of roofing materials and has set up the Cool Roof Rating Council to develop labels that inform buyers about the relative degree to which various roofing products reflect solar radiation and emit heat through thermal radiation. The building materials industry has also introduced a number of products that help increase roof reflectance, mainly elastomeric coatings, single-ply membranes, tiles, and metal roofing. The ENERGY STAR® program certifies cool roof products with its voluntary label and offers a web-based guide to ENERGY STAR roof products available on the market (http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products).

The Need for Cool Colored Roofs

Lack of cool colored products has been a major technical barrier to introducing cool roofs on residences. Existing white and non-white cool coatings are fine for the low-slope roofs of commercial and industrial buildings and apartment structures. But most homeowners don't want white on their high-slope roofs, which are seen from the street. The market for home roofing materials is dominated by colorful shingles, tiles, metal products, and wood shake.

In this Issue

As a result of a research project funded by the California Energy Commission, homeowners will soon see a variety of new "cool-colored" roofing products. Berkeley Lab's EETD is working with Oak Ridge National Laboratory, two pigment manufacturers, and 10 roofing manufacturers. The manufacturing partners produce the types of roofing materials (shingles, clay tiles, concrete tiles, and metal roofs) that cover more than 90 percent of the residential roofs in the U.S. The industrial partners are 3M, American Rooftile Coatings, BASF, Custom-Bilt Metals, Elk Manufacturing, Ferro, GAF, Hanson Roof Tile, ISP Minerals, MCA, Tile Monier Lifetile, and the Shepherd Color Company.

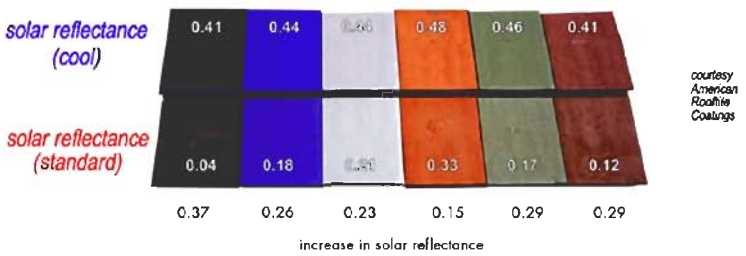


Figure 2. *Roof tiles coated with cool-color pigments are far more reflective*

Asphalt shingles account for half of the residential roofing market in the western states, according to industry sources. "Most commercially available roof shingles are optically dark," says Akbari. "Their solar reflectances range from five to 25 percent, depending on color. Even the majority of nominally 'white' roof shingles are grayish and have a solar reflectance of about 25 percent, which is much lower than the 70 percent solar reflectance of white tiles or white metal panels. Since many homeowners prefer non-white roofs, we are working to develop cool colored roofing products."

Cooler Pigments

Manufacturing a cool-colored shingle starts with finding cooler pigments. Akbari and Berkeley Lab scientists Paul Berdahl and Ronnen Levinson have been measuring the solar spectral reflectance (reflectance versus wavelength over the solar spectrum) of commercially available pigments. Figure 1 shows the distribution of solar power as a function of wavelength. For a given color, the ideal pigment reflects as much as possible of the invisible radiation in the near-infrared range.

The research team has developed a pigment database describing a variety of colors, including browns, blues, purples, greens, and reds,

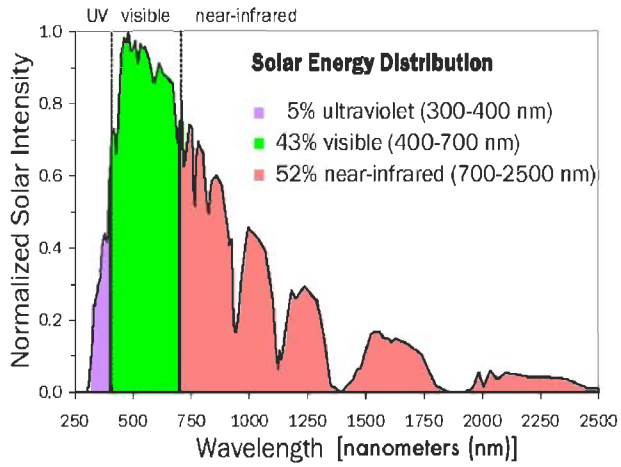


Figure 1. *Cool colors are formulated to reflect more sunlight at near-infrared wavelengths.*

that are cool, i.e., highly reflective to near-infrared radiation. Figure 2 shows some color-matched concrete tiles. Along the bottom row are tiles colored with standard pigments compared to the top raw tiles colored with cool pigments. The cool pigments typically have solar reflectances about 0.30 higher than color-matched conventional pigments (e.g., 0.40 versus 0.10).

Figure 3 compares a cool and a standard brown. To the eye, they are almost the same color, but the graphic to the left shows that the cool brown reflects about 20 percent more of the incident solar radiation than the conventional color (27 percent versus 8 percent).

In addition to testing materials in the lab, Levinson, Berdahl, and Akbari have adapted a mathematical model (the Kubelka-Munk model) to describe how pigmented coatings scatter and absorb light. They will apply the model to develop more reflective cool-colored roofing materials.

Using the pigment database and the model, the team is now developing cool-color coating design software for the roofing industry. The software estimates the reflectance of a coating using the absorption and scattering properties of the pigment as well as the coating's composition and geometry. The results are recipes for manufacturing pigmented coatings that maximize solar reflectance for a given color.

Cooler Tiles, Metal Panels, and Shingles

The next step is to figure out how to apply pigments to relatively simple roofing products such as tiles, metal panels, and shingles. The team has identified a number of cool pigments appropriate for coating metal panels and concrete and clay tiles. (Tile roofs are increasingly preferred on more expensive houses in the western and southern states.) One manufacturer of metal roofing has already switched most of its product line to cooler coatings because the product made with the cool pigments costs about the same as that made with conventional pigments, and the solar reflectance features adds value for customers.

The research team's current efforts focus on asphalt shingles, a challenging technical problem. Shingles are produced in a multi-step process: roofing granules (small crushed rocks) are manufactured, color is applied to them, and the granules are then used to cover asphalt-saturated fiberglass sheets.

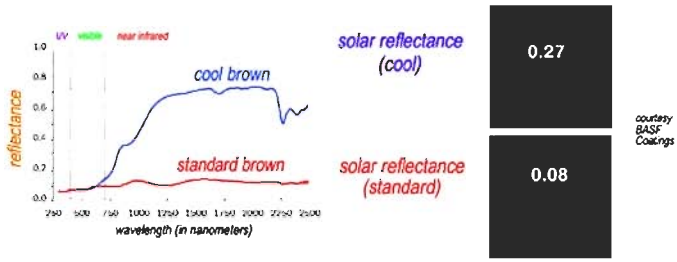


Figure 3. *Cool and standard brown metal roofing panels.*

The EETD team and its industrial partners have developed a two-layer system for manufacturing cooler roofing granules. In this process, granules are pre-coated with an inexpensive pigment that is very reflective at near-infrared wavelengths. Then, the cool-colored pigment is applied. The first pigment helps increase the reflectance of granules and reflects even more light than the cool-colored pigment would if it were by itself. The two pigments together significantly reduce the amount of near-infrared light absorbed by the granules' dark surface.

EETD's industrial partners have now manufactured more than 50 prototype cool shingles, 30 tiles and tile coatings, and 20 metal panel prototypes, including a cool black shingle that is 18 percent reflective, well above the four-percent reflectance of conventional black shingles.

Field Testing and Market Acceptance

To test the field performance and durability of these cool coatings, EETD is collaborating with Oak Ridge National Laboratory. The Oak Ridge team has set up a steep-slope assembly test apparatus (Figure 4) on its grounds in Oak Ridge, Tennessee, to evaluate a variety of samples from the manufacturing partners. Andre Desjarlais, William Miller, and their associates have installed representative cool roofing materials at the Oak Ridge roof testing facility and are measuring the changes in physical composition and appearance of the samples as a result of exposure to ultraviolet light, weathering, and temperature changes.

The joint Berkeley Lab-Oak Ridge team has also set up seven test sites throughout California, in six climate zones ranging from mild to severe, to monitor the performance of roofs using test materials from the manufacturing partners. The sites range from the far north of the state, to the California-Mexico border. The project team is also collaborating with the Sacramento Municipal Utilities District to measure energy savings and changes in temperature and humidity inside test houses with cool roofs in Sacramento, California.

Several of the new cool coatings are already available through the manufacturing partners.

"Since the start of this research," says Akbari, "the solar reflectance of commercially available clay and metal products has increased from the five to 25 percent range to the 30 to 45 percent range. Working with our industrial partners, we hope to produce shingles with a solar reflectance of 25 percent or higher, qualifying for an ENERGY STAR cool roof label. Some of the products resulting from this research will also qualify as cool roofs in the California building energy code (the 2005 Title 24 California Building Energy Efficiency Standard)."

— Allan Chen

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The Cool Colors project:
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Berkeley Lab's Heat Island Group
http://heatisland.lbl.gov/

ENERGY STAR Roofs
http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products

California Building Energy Code (Title 24)
http://energy.ca.gov/title24

This research is funded by the California Energy Commission and the U.S. Department of Energy.

Figure 4. *Testing cool-colored roof materials at Oak Ridge National Laboratory on the Envelope Systems Research Apparatus.*

BVAMP: Simplifying Assessment of Building Vulnerability

Building comfort, safety, efficiency, and cost reductions are serious matters that traditionally occupy building managers' time. However, in light of recent world events, building managers face an additional concern: the threat of a chemical, biological, or radiological (CBR) attack.

Federal and other agencies (e.g., the American Society of Heating, Refrigerating, and Air-Conditioning Engineers; the National Institute for Occupational Safety and Health; and the Federal Emergency Management Agency) are developing tools and protocols to understand CBR threats. However, applying these tools can raise complex questions; for example, which action should a building manager take first? What are the costs of improvements to thwart an attack? What degree of threat might a building face? In many cases, only a site-specific analysis can answer these questions.

To help facility managers with this complex task, Environmental Energy Technologies Division (EETD) researchers Tracy Thatcher and others at Lawrence Berkeley National Laboratory (Berkeley Lab) have produced the Building Vulnerability Assessment and Mitigation Program (BVAMP), a user-friendly tool that assesses a building's vulnerability to attack and can also offer building-specific recommendations. Funded by the California Energy Commission (CEC) Public Interest Energy Research (PIER) program, this interactive web program also attempts to minimize the energy penalties that may be associated with improving heating, ventilation, and air-conditioning (HVAC) systems to withstand CBR attacks.

Know the Building

BVAMP users first answer questions about their buildings' access, risk assessment, emergency response plans, and HVAC systems and controls. The questions are hierarchical; a "yes" answer takes the user to one set of questions, and a "no" answer leads to a different category.

Knowledgeable building managers can often reduce the likelihood or severity of a CBR attack by looking at three general building categories: HVAC system control and operation, building system security, and emergency response planning.

The HVAC system is an important but often overlooked element in reducing a building's vulnerability. HVAC [particle and chemical (gas)] filters can very efficiently remove unwanted airborne agents. A filter upgrade can increase the percentage and type of pollutants removed although in some cases, the additional air pressure required to handle a higher-efficiency filter may require some re-engineering of HVAC fans.

Although simply being inside a building itself provides some protection during an attack, modifying the operation of the HVAC system during an emergency can significantly reduce the impact of a CBR release, potentially saving lives and reducing property contamination. For example, if a tank car carrying a toxic chemical overturns near a building, turning off the HVAC system will reduce the chemical concentration that is carried indoors. Because quick and efficient evacuation of densely populated areas is typically not possible, people are more likely to survive an attack if they shelter in a building that has prepared for chemical emergencies and in which the HVAC system can be quickly shut down to reduce indoor exposures.

Reducing the air exchange rate or leakiness of a building can further reduce occupants' exposure to an accidental or intentional release of CBR agents. Lowering air exchange rates reduces the speed

at which outdoor contaminants can enter a building, thereby lowering indoor concentrations and increasing the length of time during which people can safely shelter indoors. (Reducing building leakage may also improve occupants' comfort by eliminating drafts, improving moisture control, and increasing energy efficiency, depending on current building conditions). In addition, reducing the airflow between areas where CBR exposure is most likely, such as lobbies and mailrooms, and the rest of the building can reduce the exposure of occupants outside these high-rise areas.

In addition to improving HVAC control, increasing the security of building systems and building system information is also desirable. Making access to a building difficult can thwart potential terrorists. Many improvements are low cost; however, they may require changes in the way building management shares information and therefore be difficult to implement. The recommendations in BVAMP deal with security as it pertains to HVAC and CBR agent vulnerabilities. They do not deal with threats posed by bombs, thefts, or other issues, which can be addressed by other programs and local law enforcement agencies.

The third key aspect of vulnerability reduction and mitigation for buildings is emergency-response planning. Up-to-date and complete emergency-response plans are a crucial component of any vulnerability reduction strategy. Pre-planning and employee awareness, coupled with a well-thought-out and rehearsed emergency plan can reduce confusion and save lives during an actual emergency. Many of the measures recommended for preparing for CBR attack are also helpful for responding to other types of emergencies, such as fires or tornadoes.

Using BVAMP

BVAMP is a freestanding Java application. After start up, a set of tabbed panes appears with a series of yes-or-no questions. Users can complete the questionnaires in any order or save to a profile to return to later. After questions are answered, BVAMP saves relevant recommendations to a plain text file, which is opened using a word-processing program.

The recommendations report consists of two sections. The first gives general information and building-specific recommendations grouped into the following categories: Emergency Response Plans, Shelter-in-Place Rooms or Zones, HVAC System, Air Exchange Rate Reduction, Security, and Special Risk Areas. For each category, building- specific recommendations are grouped by cost (higher and lower) and by risk category (actions warranted for all facilities and actions most appropriate for facilities that face high risk). The second section of the report lists all of the questions and answers given. Some questions may be listed as unanswered, which either means that the user skipped the question or that the program skipped the question based on previous answers. For instance, if the user answers that his/her building does not have a mailroom, the program will not present any further questions regarding mailroom security, and all mailroom questions will be marked as unanswered.

Addressing Vulnerabilities

Although the probability of a CBR event in or near a building is low, the consequences of such an event could be catastrophic. Accidents involving tanker cars, hazardous materials trucks, chemical manufacturing facilities, and refineries are among the risks many buildings face. Of additional concern is the risk of deliberate attack by terrorists using hazardous materials. BVAMP is the first field tested, easy-to-use protocol that building owners and operators can use to reduce the likelihood and severity of a CBR event. BVAMP can help building managers improve emergency preparedness in a cost effective and efficient manner. Increased preparedness reduces the likelihood and severity of a CBR event.

—Ted Gartner

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Research Highlight

Examining Airline Cabin Air Quality

The U.S. Department of Transportation's Federal Aviation Administration will establish a new "Center of Excellence" to examine cabin air quality and study chemical and biological threats in airliners. Researchers from the Environmental Energy Technologies Division's Indoor Environment Department and several universities will participate in the "Air Transportation Center of Excellence for Airliner Cabin Environment Research." The Principal Investigators are William Fisk and Thomas McKone. The Center will study cabin air quality and assess chemical and biological threats. Universities taking part in the effort include Auburn, Purdue, Harvard, and the University of California at Berkeley, Kansas State, Boise State, and University of Medicine and Dentistry of New Jersey. The Center will receive at least $1 million in funding the first year.

For more information about the FAA's Centers of Excellence program visit the Center's website at http://acer.eng.auburn.edu/

NARAC Expands its Reach: Minimize Chemical-Biological Weapons Casualties

In a boost for homeland security, the National Atmospheric Release Advisory Center (NARAC) will soon be able to track and predict the movement of chemical and biological agents and other hazardous material indoors as well as outdoors.

The expanded capability is the result of a two-year collaboration between NARAC, based at Lawrence Livermore National Laboratory (LLNL), and a team from the Environmental Energy Technologies Division (EETD) at Lawrence Berkeley National Laboratory (Berkeley Lab).

"NARAC is a widely used tool for pre-event emergency planning," said EETD's Ashok Gadgil, "but planners currently only have information about outdoor concentrations. This new capability will give planners and emergency commanders access to accurate, real-time estimates of indoor and outdoor toxics concentrations, which provide a basis for informed evacuation decisions. Remaining indoors can be much safer than trying to evacuate," Gadgil added. "The improved NARAC system will finally provide data on which to base these decisions."

The NARAC enhancement is part of a Berkeley Lab-led program to minimize casualties in buildings and transportation facilities from both outdoor and indoor releases of chemical or biological weapons.

Inspired in part by the October 2001 anthrax mailings, the multi-lab effort is aimed at helping the nation's building managers, emergency planners, and first responders understand how to prepare for and respond to a chemical or biological release.

NARAC provides an automated, state-of-the-art atmospheric modeling capability that can predict the movement of nuclear, radiological, chemical, and biological releases in the atmosphere and estimate their potential effect on exposed populations.

NARAC has traditionally focused on outdoor releases; "the Berkeley Lab team's specialty is indoor aerosol transport and fate," said NARAC's Gayle Sugiyama. "We are collaborating with them on developing building

Figure. *Control room at the National Atmospheric Release Advisory Center at Lawrence Livermore National Laboratory.*

infiltration modeling capabilities to predict indoor concentrations from outdoor releases and integrating them into the NARAC system."

To create the models, the team compiled air infiltration measurements from 70,000 homes and developed a statistical method to predict the distribution of air infiltration for every 8,000-resident census tract in the United States. A key feature of the model is that predictions can be made for particularly "leaky" or "tight" houses as well as typical houses in each area. Sugiyama said a new infiltration model for residential buildings is now being tested, and the team recently began work on an approach for commercial buildings.

Gadgil's research group provides advice for building operators through its "Secure Buildings" website (securebuildings.lbl.gov), which has had thousands of visitors viewing more than 40,000 pages since early 2002. Airflow and Transport Group began to make recommendations on preparation, training, and response to emergency events in work that began in the late 199s. They created first-responder training materials for the California Peace Officers Standards and Training Agency, which has used the materials to train police officers throughout the United States.

"These efforts have improved the readiness and safety of the nation's police officers, the security of the nation's buildings and their inhabitants, the effectiveness of local emergency response, and the safety of the U.S. air transportation network," Gadgil said. "A major attack may still have consequences, but they will be lessened because of the project's scientific work and outreach."

The NARAC, which is part of the U.S. Department of Energy (DOE), supports the Nuclear Incident Response Teams, the Federal Radiological Monitoring and Assessment Center, the Department of Homeland Security (DHS) under a DOE-DHS memorandum of agreement, and 40 DOE and Department of Defense on-line sites, as well as a number of state and local agencies. The NARAC system includes both stand-alone local plume modeling tools for end users' computers, and web- and internet-based software for access to advanced modeling tools and expert analysis from the national center at LLNL.

—Charlie Osolin

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How to Buy Green Power

How do you buy power from renewable energy providers, or make the case for the business benefits of green power? A new document, incorporating technical advice from EETD researchers, as well as other institutions, can show the way.

The ***Guide to Purchasing Green Power*** is a joint product of four key agencies who are supporting the development of green power markets: the DOE's Federal Energy Management Program (FEMP), the U.S. Environmental Protection Agency's Green Power Partnership, the Sustainable Enterprise Program of the World Resources Institute (WRI), and the Green-e Renewable Energy Certification Program administered by the Center for Resource Solutions.

EETD's Rich Brown and Bill Golove were lead authors and coordinated the preparation of the document. Independent consultant Ed Holt also contributed to the guidebook. The authors expect it to be useful to businesses, government agencies, universities, and organizations that want to diversify their energy supply and reduce the environmental impact of their electricity use. The *Guide* incorporates advice from dozens of experts, including facilities and energy managers, buyers, and researchers.

"It represents a consensus of the lessons learned over the last six-plus years about the best ways to buy green power," says Brown. "The *Guide* is the closest thing there is to an 'official' guide from the federal government for organizations that want to buy green power."

"Most organizations are new to buying green power, but an increasing number are planning purchases in the future," says Golove. "Several key organizations recognized the need for information to help turn this interest into actual purchases. We felt it would be valuable to the market to develop a guidebook that represented consensus guidelines and collective wisdom about what's been learned in procuring green power for institutions."

The *Guide* answers questions about renewable energy and green power, focusing on electricity from renewable sources. It describes environmental benefits and provides organizations with guidelines on how to procure green power and understand green power product certification and verification. Finally, sections of the *Guide* describe how organizations can approach the development of on-site renewable power generation.

Download the guide at:
http://www.eere.energy.gov/femp/technologies/renewable_purchasepower.cfm
http://www.epa.gov/greenpower/buygreenpower/guide.htm
http://www.thegreenpowergroup.org/publications.html
http://www.resource-solutions.org/

The research was funded by DOE's Federal Energy Management Program, the Environmental Protection Agency, the World Resources Institute, and the Center for Resource Solutions.

New Federal Efficiency Standards for Residential Furnaces and Boilers: EETD Researchers Estimate Potential Impacts

Seventy percent of U.S. homes have furnaces, and 11 percent have boilers; space-heating equipment accounts for more than 70 percent of gas consumption and 90 percent of oil consumption in the U.S. residential sector. In view of these statistics, the U.S. Department of Energy (DOE) in 2002 initiated an update of the current minimum energy-efficiency standard for furnaces and boilers, which was established in 1992. A team of researchers from the Energy Efficiency Standards (EES) Group of the Environmental Energy Technologies Division (EETD) at Lawrence Berkeley National Laboratory (Berkeley Lab) carried out much of DOE's analysis of the potential impacts of the updated standards. Under the leadership of Alex Lekov and Jim Lutz, the team participated in the rulemaking process, which included a number of workshops with stakeholders to discuss the analysis and key issues affecting it. Based on the EES team's analysis, DOE published an Advance Notice of Proposed Rulemaking (ANOPR) in the Federal Register in July 2004.

Furnace and Boiler Technology

For statutory purposes, residential furnaces are defined as having a heat-input rate of less than 225,000 British Thermal Units (Btus) per hour. Residential boilers are defined as having a heat-input rate of less than 300,000 Btu/h. Residential furnaces supply heated air through ductwork to interior spaces. Residential boilers are pressure-vessel heat exchangers made of cast-iron, steel, aluminum, or copper and designed to burn fossil fuels and transfer the released heat to a suitable medium such as water (in water boilers) or water and steam (in steam boilers).

Annual fuel utilization efficiency (AFUE) is the measure of the annual operating efficiency, under dynamic conditions, of a furnace or boiler. AFUE is measured under laboratory conditions using a DOE test procedure. The 1992 efficiency standards specify the following AFUEs for residential space heating equipment:

- gas- and oil-fired furnaces—78 percent,
- manufactured home furnaces—75 percent,
- hot-water boilers—80 percent, and
- steam boilers—75 percent.

Most new furnaces and boilers have higher AFUEs than required by the 1992 standard. New furnaces generally fit into one of two general efficiency categories: non-condensing furnaces with AFUEs of 80 to 82 percent or condensing furnaces with AFUEs at or greater than 90 percent. Most new hot-water boilers have AFUEs of 80 to 84 percent.

Product Classes

For statutory purposes, residential furnaces and boilers are divided into several product classes that may be subject to different efficiency standards. For the current update of efficiency standards, DOE considered the following product classes: weatherized and non-weatherized gas furnaces, non-weatherized oil-fired furnaces, mobile-home gas furnaces, and gas- and oil-fired hot-water boilers. Non-weatherized gas furnaces have by far the largest sales among these classes (approximately 2.6 million units in 2000), so the EES team gave the most attention to this class.

Analyses

The EES team's work for the ANOPR:

- Assessed the market and technology,
- Screened technology options,
- Assessed the cost and efficiency of technology options,
- Determined the energy consumption of alternative designs in actual homes,
- Calculated life-cycle cost (LCC) and payback period for actual households,
- Projected future shipments (installations), and
- Calculated national energy savings and net present value.

The team also analyzed options for improving the efficiency of furnace and boiler electricity use, but these were not included in the ANOPR because DOE determined that it does not have authority to set efficiency standards that include furnace electricity use. The ANOPR analysis did, however, account for the effects of fuel-saving options and electricity consumption.

Key Issues

Analysis of furnace and boiler standards is complicated because installation cost, which is the second largest single component of total consumer cost (after lifetime energy costs), varies considerably depending on the type of venting system required to prevent condensation and ensure safe operation of the equipment. For non-condensing furnaces, a key task facing the EES team was to estimate the percentage of installations that are likely to require a stainless-steel, Category-III venting system, which is considerably more expensive than a conventional (Category-I) system. For furnaces that utilize single-stage controls—currently the most common type—the EES team estimated that eight percent of installations at 81-percent AFUE and 40 percent of installations at 82-percent AFUE would require a Category-III venting system. However, for 81-percent AFUE, current installation practices indicate that furnaces that use two-stage modulating control would not require this expensive type of venting. Better understanding of the actual installation costs associated with 81-percent AFUE gas furnaces is a key factor in determining whether a more stringent standard (than the current 78-percent AFUE) would be cost effective.

Key Findings

Key measures that DOE considers in determining whether new standards are justified include the cumulative National Energy Savings (NES) and the Net Present Value (NPV) of consumer costs and benefits for equipment installed in the period between 2012 and 2035, the average LCC savings from purchasing and operating a more efficient appliance, the percentage share of households purchasing an appliance that would have a positive or a negative LCC impact, and the median payback period for the higher cost of a more efficient appliance.

For each product class, Table 1 shows key results for the highest efficiency level that has a positive NPV, using either a seven-percent or a three-percent real discount rate. The largest national energy savings come from the standards for non-weatherized gas furnaces, followed by those for hot-water gas boilers and weatherized gas furnaces. These three product classes also have the highest projected shipment volumes. Figure 2 shows the LCC cost savings for different design options.

For non-weatherized gas furnaces, an AFUE standard of 81 percent has a clearly positive NPV only for a furnace using two-stage modu-

Table 1. *Projected impacts of standards at highest efficiency level with positive NPV.*

	Non-weatherized gas furnace*		Weatherized gas furnace	Mobile home gas furnace	Non-weatherized oil furnace	Hot-water gas boiler	Hot-water oil boiler
AFUE (%)	81(A)	81(B)	82	81	83	83	83
National energy savings (quads)	1.12	0.44	0.18	0.02	0.05	0.24	0.03
Net present value (billion 2001 $) 7% real discount rate	0.75	-0.29	0.14	0.01	0.11	0.33	0.07
3% real discount rate	3.22	0.06	0.43	0.03	0.29	1.10	0.20
Average LCC savings ($)	$62	$-3	$56	$115	$203	$215	$79
Households with net LCC benefit (%)	41%	45%	77%	85%	75%	79%	39%
Households with no net LCC impact (%)	27%	27%	20%	5%	22%	15%	61%
Households with net LCC cost (%)	32%	29%	3%	10%	3%	6%	0%
Median payback period (years)	7.6	8.8	2.1	4.2	0.3	2.5	0.7

**A=furnace using single-stage modulating controls (no Category-III venting system required; B=furnace using two-stage control (8% of installations require Category-III venting system).*

lating controls. With this type of furnace, 41 percent of households would experience LCC savings, 27 percent would experience no change, and 32 percent would experience an increase in LCC. The results for a furnace using two-stage modulating controls are based on energy consumption calculated using the current DOE test procedure. This procedure differs from the proposed revision of the relevant American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) standard, which indicates that the energy savings from two-stage modulation may be less than those calculated using the DOE test procedure.

Outlook

In July 2004 DOE posted the ANOPR and the ANOPR technical support document on its website for residential furnaces and boilers [http://www.eere.energy.gov/buildings/appliance_standards/residential/furnaces_boilers.html]. Under direction from DOE, the EES team will review and consider stakeholder comments as it revises the analysis and conducts new analyses of impacts on manufacturers, utilities, employment, and emissions of air pollutants and carbon dioxide. The updated analysis will account for proposed changes to the furnace test procedure. If DOE concludes that new standards are justified, they would take effect in 2012.

—Alex Lekov, James Lutz, Steve Meyers

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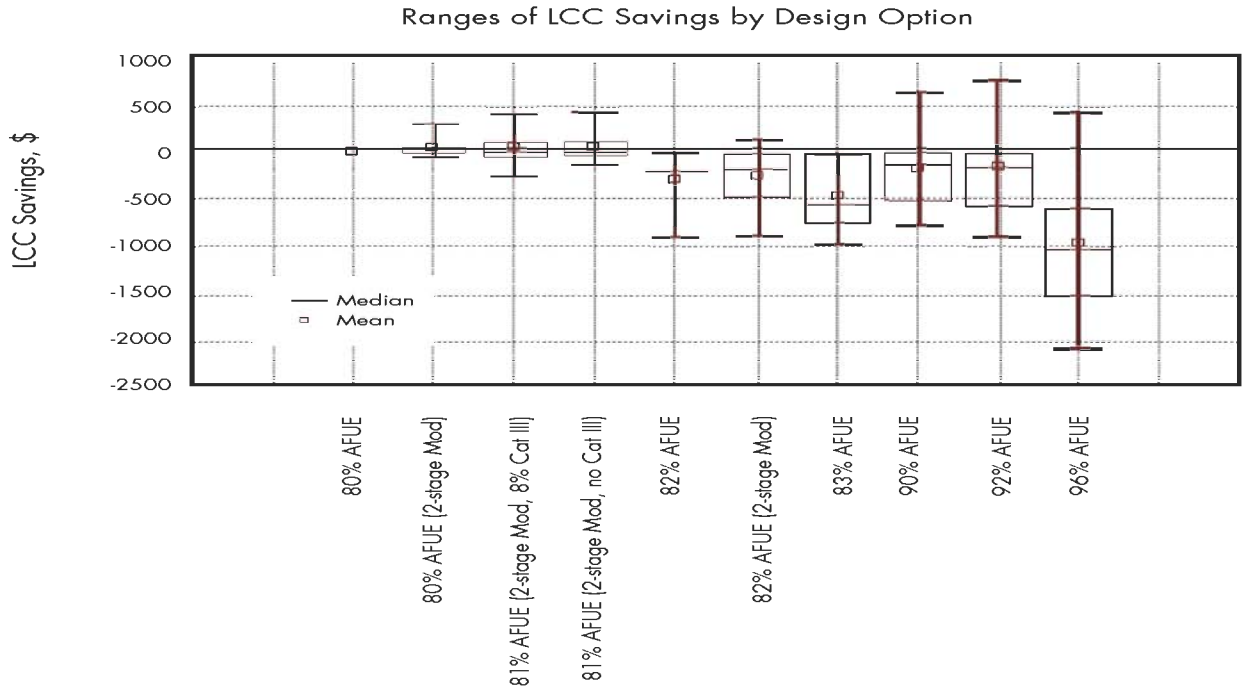
Figure 1 *shows the range of life-cycle cost (LCC) savings for non-weatherized gas furnaces. The average baseline LCC for this product class is $9,800 (the average total installed cost is $2,000, average operating cost is $600, discounted over a 20-year lifetime at 6.3% real) For each design option, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median; 50 percent of the households have LCC savings above this value. The "whiskers" at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each design option. For condensing design options such as 90 percent AFUE and 92-percent AFUE, the wide range of LCC savingsreflects the differences across regions of the country.*



Research Highlights

EETD Scientists Tackle Afghani Housing

Twenty-six years of war and frequent earthquakes have badly damaged Afghanistan's housing stock and infrastructure. Earthquake damage has been severe—Afghanistan is in one of the world's most active zones—because traditional buildings have adobe walls supporting wooden rafters and roofs made of straw mats and mud. In Afghanistan's ravaged economy, modern construction methods are much too expensive to be useful.

Deciding a new approach was necessary, Henry Kelly, president of the Federation of American Scientists, challenged the U.S. academic and scientific communities (including Lawrence Berkeley National Laboratory) to find a better way to build sturdier houses. The criteria were that the houses needed to be lightweight, easy to construct, and use no wood because of the scarcity of trees in Afghanistan. In addition, the structures had to be attractive to the population; comfortable in extreme climates; and secure in wind, fire, and earthquakes.

One of Kelley's friends proposed just the right thing: Styrofoam. It's lightweight, heat resistant, cheap, and strong. A 24-foot panel with a four- to 12-inch-thick core of expanded polystyrene sandwiched between two half-inch sheets of cement is sufficiently strong to support a 3,400-pound pickup truck.

Berkeley Lab scientists Ashok Gadgil, Hashem Akbari, and Rick Diamond are on the steering committee that will evaluate the housing materials' suitablity. The committee has already simulated the performance of a foam home to determine the appropriate wall thickness and window size. The group even set a mock-up on fire at a testing lab and watched the fire-resistant foam literally back away from the flames.

In the U.S., structural insulated panels systems (SIPS) are slowly becoming part of modern construction. One industry official estimates that the application of these panels is growing by 15 percent per year. In addition to the energy saved by the panels, construction time is shortened because they are easy to work with. The real test will be when homes are constructed with panels in Afghanistan and other parts of the world. Costs will be low, but will people buy the idea of living in a Styrofoam house?

Wray Honored with Distinguished Service Award

Craig Wray, a mechanical engineer in EETD's Energy Performance of Buildings Group, was recently honored with the ASHRAE Distinguished Service Award. Wray has a 20-year history of service to ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) that includes participating on numerous technical, research, and standards committees, as well as conducting building energy calculation and smoke control research on behalf of the Society. Most recently, he was the Chair of the Ventilation Requirements and Infiltration technical committee and is now a member of the Technical Activities Committee, which coordinates all of the Society's technical work in the fields of heating, ventilation, air conditioning, and refrigeration.

The award is given to those individuals who have served the Society with distinction and given their time and talent on its behalf. Wray says that his efforts already have been repaid many times over by the benefits of the Society, which include early access to information about state-of-the-art technology, as well opportunities for networking, leadership, and professional development.

Gadgil Wins Tech Museum Award

San Jose, California's Tech Museum Awards program has given EETD's Ashok Gadgil a $50,000 prize for his UV Waterworks technology.

Gadgil won the "The Affymetrix Health Award." He is one of five 2004 Tech Museum Awards laureates awarded $50,000 for their pioneering work. The Museum encourages them to reinvest their winnings in innovative technology to solve global challenges and improve the lives of people around the world.

"I am greatly honored by this recognition of the enormous potential of UVWaterworks technology to reduce the global health impact of unsafe drinking water. This technology can provide affordable access to safe drinking water for hundreds of millions of people." Gadgil said.

More than four million people, mostly children, die annually from dirty drinking water. Gadgil's invention of UVWaterworks, a robust, inexpensive and effective technology to disinfect drinking water, reduces the cost to treat a person's annual drinking water supply to about $1.50. This invention makes safe drinking water affordable to the 1.2 billion people forced to rely on dirty drinking water, most of whom earn less than a dollar a day. For more information, see www.techawards.org.

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With more than 3,500 employees, Berkeley Lab's total annual budget of nearly $500 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 nine Nobel laureates. EETD is one of 17 scientific divisions at Berkeley Lab, with a staff of 400 and a budget of $40 million.

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