Energy Design Update®

The Monthly Newsletter on Energy-Efficient Housing

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INDUSTRY NEWS

Planning For Foam Shrinkage

Manufacturers of rigid foam insulation and the US Department of Energy agree that foam sheathing can be installed on walls as a water-resistive barrier (WRB) —that is, instead of asphalt felt or housewrap. However, most residential building codes do not yet permit the use of rigid foam as a WRB, and the necessary flashing details remain in dispute (see ***EDU***, December 2004 and July 2006).

Builders considering using foam sheathing as a WRB need more than code approval; they also need to be assured that rigid foam products are dimensionally stable enough to shed water dependably. According to Timothy Lenahan, the residential programs manager for the Ohio Energy Office, extruded polystyrene foam is prone to so much shrinkage that it shouldn't be used as a WRB. He reached that conclusion after observing shrinkage patterns in the foam sheathing on his own house.

Figure 1. The Dow Styrofoam sheathing on Timothy Lenahan's Ohio house was installed in 1977.

The Tongues Pulled Out Of the Grooves

When Lenahan's home was built in 1977, the unknown builder sheathed the walls with ¾-inch-thick extruded polystyrene insulation, attached with long roofing nails directly to the studs. Aluminum siding was then nailed to the studs through the Dow Styrofoam (see Figure 1). "I was removing the siding so I could replace the windows," Lenahan recently told ***EDU***. "The first thing I noticed were some gaps at the end of the foam, and I started cursing the installers. I thought, 'You'd think they could have gotten a longer piece of foam here.' As I removed more and more siding, I found that the same thing had happened everywhere. The foam has physically pulled away from the nails, and the gaps were fairly consistent [see Figure 2]. That's a good indicator that this is not a workmanship issue. At some of

In This Issue

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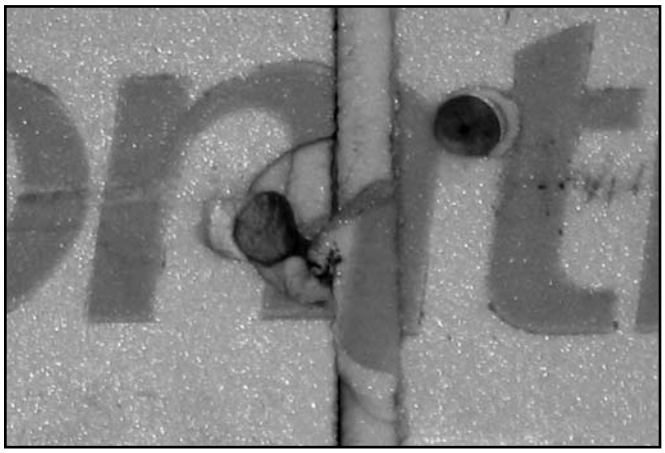

Figure 2. The deformations of the foam around each nail head are clues that the foam has been shrinking.

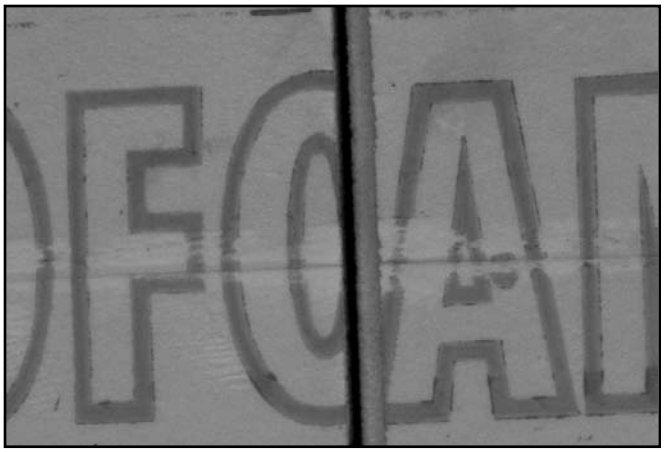

Figure 3. At some of the vertical foam joints, the tongues have separated entirely from the grooves.

these gaps, the tongue is completely out of the groove [see Figure 3], and you can see the fiberglass insulation through the gap." The fact that the fiberglass insulation has turned black is an indication that air has been moving through the gap for years (see Figure 4). "I have always felt that the walls in my house seem to get cold," said Lenahan. "I can feel radiant heat transfer to the walls."

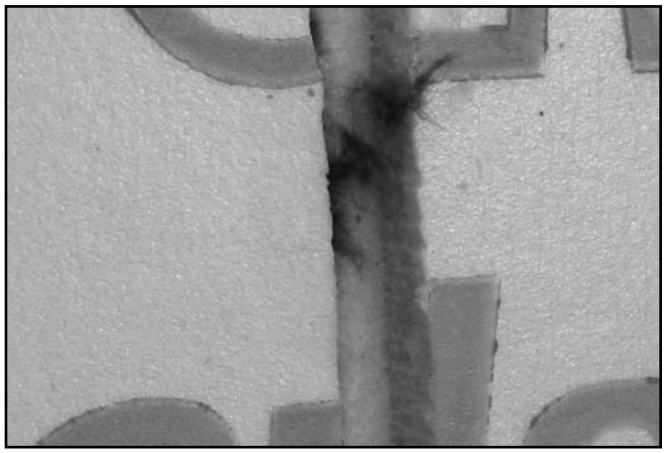

Figure 4. At the top of this photo, a wisp of dirty fiberglass insulation is visible.

After carefully examining the gaps between the Styrofoam sheets and the way that the foam deformed in the vicinity of each nail, Lenahan concluded that the Styrofoam had shrunk. "At first I thought I was going to tape all the seams with Tyvek tape, but when I pulled more siding off, and looked at the size of the gaps, I realized that tape wouldn't do any good—the gaps were too wide. If someone intended to use foam as a water-resistive barrier, I would be really concerned." Daunted by the size of the task, Lenahan decided to leave most of the siding undisturbed. "I'm not going to pull all the siding off because it's too much work," he said.

Foam Formulations Have Changed

Curious to learn more about the dimensional stability of extruded polystyrene, ***EDU*** contacted Doug Bibee, an application technology leader at Dow. After visiting Lenahan's house, Bibee concluded that the Styrofoam has, indeed, shrunk. "Photos, descriptions and observation of the 30-year-old foam from Mr. Lenahan's home appear to show ⅜ - ⅝" shrinkage of the foam in the length direction," Bibee wrote to ***EDU.*** "This is not typical of performance then or today. Formulation of the

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foam has changed over the last 30 years to comply with changing regulations and to improve performance."

Manufacturers of extruded polystyrene and polyisocyanurate have tried for years to address the issue of dimensional instability. In recent years, foam manufacturers have adjusted their formulations in hopes of limiting dimensional changes over time. In the case of polyisocyanurate, changes in blowing agents necessitated by concerns about the depletion of atmospheric ozone may have contributed to problems with dimensional stability (see "Shrinking Insulation Boards Plague Roofers" in the July 2000 issue of the *Journal of Light Construction*).

Since manufacturers are known to change foam formulations and blowing agents, and since competing manufacturers use different formulations, there is no way for a builder to know how a particular sheet of foam purchased today will act over the next 30 years. Builders who now use tape to seal vertical joints in rigid foam sheathing should probably expect taped joints to fail eventually, resulting in a reduction in the wall's water resistance and airtightness. Because of the dimensional instability of rigid foam, conservative builders should probably include housewrap or building paper behind foam sheathing.

For Lenahan, the amount of shrinkage in his Styrofoam sheathing is worrisome. "DOE needs to rethink their position on using foam as a WRB," Lenahan wrote in an e-mail to ***EDU***. "Foam is not a stable product. The idea of taping vertical joints is flawed in that the tape will fail by the shear forces that will develop as the foam shrinks. With tongue-and-groove foam, the [DOE code change] proposal wouldn't require tape at my house. But the fiberglass is heavily stained at these seams from filtering the incoming air. Unless the new foams are more stable, it is not a long-term solution."

Canada Cancels Energy-Efficiency Program

With unexpected suddenness, Canada's new conservative government has cancelled the country's seven-year-old national weatherization program, EnerGuide for Houses (see ***EDU***, March 2004). "The news was quite abrupt—it was a surprise to us," said Mary Jane Patterson, manager of the Residential Energy Efficiency Project (REEP) in Kitchener, Ontario, one of the local agencies responsible for implementing the program. "An e-mail was waiting for us when we came into the office one morning," said Patterson. "We were notified that the program was cancelled, effective that night."

Prime Minister Stephen Harper's government has cancelled not only EnerGuide for Houses, but also EnerGuide for Low-Income Households, a $500-million program that pays the full cost of weatherization work performed for low-income Canadians.

Subsidizing The Cost of Energy Audits

The EnerGuide for Houses program subsidized the cost of residential energy audits and retrofit work. As a first step, EnerGuide for Houses evaluators performed a pre-retrofit energy audit (see Figure 5). If a homeowner hired a contractor to perform recommended energy-efficiency improvements, evaluators returned to perform a post-retrofit audit. The homeowner was then eligible for a grant to cover a portion of the cost of the weatherization work. The size of the grant depended upon the results of the post-retrofit audit: the greater the improvement in home performance, the bigger the grant.

As most home performance contractors realize, an energy audit is an essential component of energy-efficiency retrofit work. Because the cost of an energy audit can be a major hurdle for many homeowners, the designers of the EnerGuide for Houses program decided that subsidizing the cost of energy audits would be a cornerstone of the program.

Energy Audits Wasteful, Government Alleges

Ironically, the demise of EnerGuide for Houses appears to be based on a misunderstanding of the purpose of residential energy audits by politicians controlling the nation's purse strings. Confusing the cost of energy audits with administrative costs, Natural Resources

Figure 5. An evaluator from the Residential Energy Efficiency Project in Kitchener, Ontario, inspects an attic during an EnerGuide for Houses audit.

Minister Gary Lunn deemed the EnerGuide for Houses program inefficient, noting that "homeowners were only getting 50 percent of the EnerGuide funding to spend on renovations."

Responding to Lunn's analysis, Mary Jane Patterson wrote a letter to the editor of a Waterloo newspaper, *The Record*. Her letter noted, "Contrary to some reports, administration costs for the EnerGuide for Houses program are low. In 2005-06, administration accounted for less than 12 percent of the total federal money spent on this program. A full 88 percent of the money went directly to homeowner benefits, either through incentive grants (54 percent) or cost-sharing for house evaluations (34 percent). Some politicians are referring to the EnerGuide for Houses evaluations as 'administration.' This is an unusual way to refer to science-based professional energy audits. The evaluations motivate homeowners, identify the cost-effective energy savings, guide the retrofit work, and measure and verify the results. Getting rid of the audits, which seems to be the government's plan, would leave the program open to fraud and waste."

Defenders of EnerGuide for Houses cite the program's undeniable effectiveness. Between October 2003 and March 2006, 52,000 homeowners have received retrofit grants averaging $680. Improvements to participants' homes lowered energy bills by an average of 28 percent—about $750 (Canadian dollars) per year.

Launching A Successful Program Takes Years

In Canada, as in the US, funding for government energy-efficiency programs depends upon the fickle whim of politicians. Developing the infrastructure required to perform home-performance audits and energy retrofits is painstaking, and the sudden evaporation of government funding can quickly dismantle years of patient work. According to Clifford Maynes, the executive director of Green Communities Canada, "The government's cancellation of the EnerGuide for Houses programs is an enormous blow to Canada's developing home energy-efficiency industry. It has the potential to set back the cause of residential energy efficiency in this country by a decade or more."

In Kitchener, Mary Jane Patterson has been able to switch some full-time REEP workers to part-time status, thereby avoiding lay-offs—at least for the time being. "Just finding trained energy advisors is very difficult," said Patterson. "Our evaluators are really experienced; they understand the houses in our region. To lose our trained staff would be really discouraging."

Widespread Consternation

Public response to the Harper government's cancellation of EnerGuide for Houses has been almost uniformly negative. An editorial in the Toronto *Star* noted, "Odds are you will not find a more effective government program than Ottawa's EnerGuide for Homes. That is why the new Conservative government's recent decision to cancel the program is a shock. . . . The $75 million that Ottawa spent on the retrofit program from October 2003 to March 2006 will yield $975 million in energy savings over the life of retrofit investments. That is a healthy return on a rather modest government investment."

Among the letters to the editor that appeared in the *Star* was one from the deputy mayor of London, England, Nicky Gavron, who expressed surprise at the program's cancellation. "Two years ago, London scoured the world for the best science-based residential efficiency program," Gavron wrote. "We found it in Canada—EnerGuide."

In an article posted on the Web site of CTV News, reporter Kathy Tomlinson wrote, "Environmental groups were already upset with the Conservatives over the lost opportunity to save energy. 'It was just tossed aside,' said John Bennett of Climate Action Network Canada. 'I don't think they put any thought into the implications of their decisions.'"

According to Patterson, the near-unanimous condemnation of the decision to cancel EnerGuide for Houses may have caught the Harper government off-guard. "It feels like people from all political backgrounds have been shocked by this move here," Patterson told ***EDU***. "I can't imagine that the government has not been barraged with e-mails."

Looking Ahead

With the sudden withdrawal of government funding, local groups implementing the EnerGuide for Houses program had to decide whether to close their doors or to find alternate sources of funding. "Since the EnerGuide for Houses program effectively belongs to the people of Canada, we are still permitted to offer services," said Patterson. "Fortunately there has been great signs of local support. Three local electric utilities have said that they would like to provide some of the subsidy that the government had withdrawn. The only difference is that there is no funding to provide homeowner grants. All three utilities were already providing some operational funding, but they have stepped up to provide even more. But the utilities have made it clear that this is only a temporary solution, so we don't know what the fall will bring."

Deborah Taylor, acting vice president of assisted housing at the Canada Housing and Mortgage Corporation (CMHC), has been dealing with the fallout arising from the cancellation of EnerGuide for Low-Income Households. CMHC briefly withheld subsidy checks from some low-income Canadians who had already contracted for retrofit work; eventually, however, CMHC received authorization to pay for any work that had already started. New applicants, however, are being turned away. "The government is doing a review of climate change opportunities, so at this point the delivery of the program remains discontinued," Taylor told ***EDU***. "We'll have to wait and see what happens in the future."

NEWS BRIEFS

A Dehumidifier That Heats Water

OAK RIDGE, TN -- Researchers from Oak Ridge National Laboratory, in collaboration with two North Carolina colleges, are developing a heat-pump water heater integrated with a dehumidifier. The idea is to perfect a humidistat-controlled unit that can provide dehumidification even when no hot water is called for. According to an article in the June 2006 issue of *In Hot Water*, researchers have built a prototype with two condensers; one coil is immersed in a water tank, while the other coil is surrounded by air. The prototype is now undergoing testing at the Asheville-Buncombe Technical Community College in Asheville, North Carolina.

Indiana Town Aims For Energy Independence

REYNOLDS, IN -- Reynolds is an Indiana farming town aiming for complete energy independence. According to an article in the *Seattle Times*, the 500 residents of Reynolds plan to generate their own electricity and methane gas using municipal trash, farm waste, town sewage, and hog manure. A few of the details remain to be worked out, of course. "It's not like we have a blueprint to follow," said farmer William Schroeder, 52. "We're going by the seat of our pants." As one of the first steps in the project, dubbed BioTown USA, construction will begin in November on a $10 million plant that will generate electricity by burning methane produced on site from hog manure. A study by the Indiana Department of Agriculture estimates that the 150,000 hogs residing within 15 miles of the town produce enough manure to generate 74 times the energy consumed in Reynolds. The local fire chief, Rick Buschman, says that BioTown is "the greatest thing to hit Reynolds" in years. He has demonstrated his enthusiasm for the project by convincing the members of his extended family to buy six new flex-fuel vehicles—vehicles than can be fueled with ethanol—as part of a special deal offered by General Motors. Schroeder, a fourth-generation farmer, noted, "I think the American people are ready for this."

Florida Launches New PV and Solar Thermal Incentives

TALLAHASSEE, FL -- Governor Jeb Bush has signed a new law (SB 888) establishing rebates for the installation of solar thermal and photovoltaic (PV) systems in Florida. For a grid-tied PV system rated at 2 kW or greater, a homeowner can apply for a rebate of $4 per watt, up to a maximum of $20,000 per house. Critics of the new legislation note that the program is seriously underfunded; only $2.5 million has been allocated for the program's first year, and most experts expect the funds to be gone within three or four months.

Hawaii Increases Solar Tax Credits

HONOLULU, HI -- Hawaii Governor Linda Lingle has signed a bill (SB 2957) increasing the level of state tax credits for the installation of solar thermal and photovoltaic (PV) systems. The maximum tax credit for a residential solar thermal system has been increased 30% to $2,250, and the maximum tax credit for a PV system has been increased 240% to $5,000.

California Study Slams Ozone Generators

SACRAMENTO, CA -- In the wake of an article in the May 2005 issue of *Consumer Reports* raising questions about the safety of "air cleaners" that generate ozone, a component of smog, a new report issued by the California Air Resources Board (ARB) has concluded that "the use of ozone generators in enclosed spaces presents a serious public health risk from exposure to ozone and its toxic by-products." According to *IEQ Strategies* newsletter, "University of California at Irvine chemistry professor Sergey Nizkorodov says some purifiers' level of ozone emissions can create the indoor equivalent of a Stage Two smog alert." To read the full text of the ARB study, "Evaluation of Ozone Emissions From Portable Indoor 'Air Cleaners' That Intentionally Generate Ozone," visit *www.arb.ca.gov/research/indoor/ozone.htm*.

Energy-Efficient Home In Maryland

BEL AIR, MD -- A Maryland builder, Bob Ward Companies, has built a show house designed to use

about 50% less energy than a typical new home. Designed with help from the Building America program, the 2,566-square-foot home includes a solar hot water system and a 3.8-kW photovoltaic system. Precast foam-insulated basement walls from Superior Walls were used for the foundation; above-grade walls include foam sheathing. The attic is insulated with R-49 fiberglass. According to an article in the Baltimore *Sun*, the house is projected to have utility bills of $173 per month. For more information, visit *www.toolbase.org/Home-Building-Topics/zero-energy-homes/zeh-maryland*.

PV-Equipped Homes In California

WATSONVILLE, CA -- California developer Clarum Homes recently began construction work at a new 74-home development, Parajo Vista, in Watsonville. Each Parajo Vista home will be equipped with a 1.5-kW photovoltaic array of Kyocera modules.

Home Buyers Uninterested In Energy Efficiency, Say Builders

NEW YORK, NY -- According to the chief executives of two of the nation's leading home-building companies, home buyers are uninterested in energy efficiency. A Reuters News story reporting on a real estate summit in New York quoted Ian McCarthy, the chief executive of Beazer Homes, who said, "I think people still look at a granite countertop and say, 'Wow, I'd really like that,' as opposed to really having energy efficiency. I think it's going to take some education." When asked about the level of interest in energy efficiency from his customers, Robert Toll, the head of Toll Brothers Homes, answered, "Zilch. Never was." Like McCarthy, Toll compared energy efficiency to granite countertops. "So far, I've gotten one call in the last year about solar panels, so apparently it hasn't hit us yet," Toll said. "The buyer is not willing to trade efficiency for granite."

High-Tech Energy-Efficient Home In Britain

STROUD, UK -- A British owner-builder, Mike Hillard, has dubbed his new $730,000 house "the most energy-efficient house in the world." Although Hillard emphasizes that his home is "environmentally friendly," the 5,000-square-foot home is anything but modest: it includes five bedrooms, two offices, a two-story sunroom, a sauna, and a hot tub. "People love to go one better than their neighbors, with faster cars and bigger houses," said Hillard. "So I decided to build a house everyone will want to own, but one that's as energy-efficient as it's possible to be." According to press reports, the high-tech house has a computer-controlled ventilation system that increases airflow when indoor sensors detect a rise in carbon dioxide levels. The home is equipped with a solar hot water system and a hypocaust to provide underfloor heating. Hillard's walls are insulated with 8 inches of fiberglass. Hillard expects utility bills of about £50 ($92) a year for space heating and £15 ($27) a year for domestic hot water. He predicts, "This house will use less than 15 percent of the energy of a normal house."

Solar Decathlon House Settled In A Permanent Location

KINGS POINT, NY -- At a ribbon-cutting ceremony in June, the New York Institute of Technology's 2005 Solar Decathlon house was dedicated at its new permanent location on the campus of the US Merchant Marine Academy in Kings Point. The two schools collaborated on the design and construction of the Decathlon house, which is equipped with a hydrogen fuel cell. The building will be used as a renewable energy research center.

GE Introduces Packaged PV Systems

SAN FRANCISCO, CA -- GE Energy has released a new line of packaged residential photovoltaic (PV) systems under the trade name Brilliance. The Brilliance systems, available in several sizes ranging from 1 kW to 10 kW, will be based on GE's 66-watt PV module.

Aiming For Net Zero In South Korea

DAEJON, SOUTH KOREA -- Engineers at the Korea Institute of Energy Research have completed two net-zero-energy buildings at their Daejon campus as part of a project called "Zero-Energy Town." According to an article in the Honolulu *Star Bulletin*, the smaller building is a single-family residence, while the larger four-story building contains apartments and offices. Electricity for the two buildings is generated on site by photovoltaic arrays and a wind turbine. Choi Ik-Soo, the Institute's president, said, "We want the buildings to be self-sufficient in terms of energy, using 100 percent new and renewable energy based on wind power, solar energy, and fuel cells."

Residential Green Project in British Columbia

LANGLEY, BRITISH COLUMBIA -- Yorkson Village, a new 55-unit residential development under construction in Langley, is being described as Canada's first green community. The builder, Morningstar Homes, is touting the homes' energy-efficiency features: R-12 basement insulation, Energy Star low-e windows, sealed-combustion furnaces, sealed ductwork, and Energy Star appliances. About 25% of the homes' lighting fixtures will be equipped with compact fluorescent lamps. The houses are priced at $460,000 to $510,000 (Canadian dollars). For more information, visit *www.morningstarhomes.bc.ca*.

ORNL Engineers Develop Hybrid Solar Lighting System

OAK RIDGE, TN -- Engineers at the Oak Ridge National Laboratory have developed a solar hybrid lighting system that uses a 48-inch-diameter roof-mounted parabolic collector to gather sunlight that is transmitted to ceiling fixtures through fiber-optic cables. Each ceiling fixture also includes electric lamps; a controller dims the electric lamps as sunlight gets brighter. One parabolic collector can serve up to 12 ceiling fixtures or 40 accent fixtures. "With 24 percent of the energy use of commercial buildings attributed to artificial lighting, we believe the time is right for this energy-efficient technology to help commercial building owners save energy while also creating jobs and helping the environment," said Duncan Earl, one of the co-developers of the hybrid solar lighting system. The new technology has been commercialized by a start-up company called Sunlight Direct; for more information, visit *www.sunlight-direct.com*.

Drilling a Three-Mile Deep Hole is Tricky

MILTON, QUEENSLAND, AUSTRALIA -- Australian engineers hoping to tap the energy stored in hot rocks deep below the surface of the earth have suffered a series of technical setbacks. According to the plan announced by an Australian company, Geodynamics, engineers intended to drill two parallel wells to a depth of about three miles; cold water would then be pumped down one hole, so that hot water could be extracted out of the second hole (see the "News Briefs" section of ***EDU***, June 2003). The extracted hot water would be used to generate electricity. In 2003, Geodynamics began drilling the first well, Habanero #1. According to an article in *EERE Network News*, that well was successfully drilled to a depth of 2.75 miles. At the second well, Habanero #2, the drill rod broke when the bit reached a depth of 2.6 miles. Engineers then began to drill a "sidetrack" well adjacent to the abandoned well; this drilling operation was aborted when a plug got stuck in the well. The next "sidetrack" drilling operation was abandoned when the drill pipe got stuck. The drill pipe had to be severed, leaving a quarter-mile length of pipe blocking the bottom of the well. In spite of all of the setbacks, Geodynamics Limited remains undeterred, and has announced plans to drill another well.

In Northwest, CFLs and Energy-Saving Washers Make Gains

PORTLAND, OR -- Consumer acceptance of compact fluorescent lamps (CFLs) and Energy Star clothes washers in the Northwestern states is steadily increasing, according to a report by the Northwest Energy Efficiency Alliance. In 2005, sales of CFLs in Washington, Oregon, Idaho, and Montana reached 6.8 million lamps, exceeding the Alliance's goal of 6.1 million. In the same year, sales of energy-efficient clothes washers in the Northwest were strong, with 46% of all clothes washers sold meeting Energy Star specifications, as opposed to 36% nationally. The full report, "Market Progress Evaluation Report for the Northwest Energy Efficiency Alliance's Energy Star Consumer Products Program," can be downloaded from the Web at *www.nwalliance.org/resources/reports/ES06-156.pdf*.

New Edition of *Green Building Products* Guide

BRATTLEBORO, VT -- The publisher of *Environmental Building News*, BuildingGreen, has just published a second edition of *Green Building Products*, a directory of environmentally appropriate building materials. The criteria for inclusion in the guide include the percentage of recycled content, avoidance of toxic materials, and contributions to energy or water savings. The book is available for $39.95 from BuildingGreen; Tel: (800) 861-0954; Web site*: www.buildinggreen.com*.

Greece Announces New PV Feed-In Tariffs

ATHENS, GREECE -- The Greek parliament has voted to raise the price paid to owners of photovoltaic (PV) systems for electricity fed into the grid from 0.07 euros per kWh to 0.45 euros per kWh, with a guarantee that the price will remain unchanged for the next 20 years. The sixfold increase in the feed-in tariff will be a huge boon to owners of PV systems in Greece.

PV-Equipped Housing In South Africa

CLANWILLIAM, SOUTH AFRICA -- Each of the 100 homes at a residential project under construction in Clanwilliam will be equipped with a photovoltaic (PV) system and a solar hot water system. The developer, Group Three Properties, calls the project "South Africa's first solar-powered village." According to an article in the Johannesburg *Sunday Times*, the designer of the PV systems, Michel Malengret of the University of Cape Town, sized the systems to provide all of the electricity required by the development's residents. A few important details remain unresolved, however, since the South African government has not yet established any standards for grid-connected PV systems. Malengret noted, "South African electrical supply authorities still need the necessary legislation and standards to allow for grid-connected electrical power sources. Most developed countries have had these well defined for more than a decade. What is taking them so long?"

Quote Without Comment

"If you keep your computer monitor on all the time,

that will cost you 60 cents a day, or $18 a month. And if you fall asleep watching television, you'll find that you'll pay about $6 a month for the privilege. (This is considering you pay about $.10 a kilowatt and sleep eight hours on average). Keeping your cell phone and battery charger plugged in may cost you $1.50 a month. The Alliance to Save Energy estimates that on a national level, these vampire devices use about 5% of our energy and cost consumers more than $8 billion annually." ["Energy-Saving Myths," by Gerri Willis, CNNMoney.com columnist, April 6, 2006]

RESEARCH AND IDEAS

Investing $9,729 Lowers Energy Use 44%

If a new 2,600-square-foot house in Sacramento, California, were to receive $9,729 in energy-efficiency improvements, energy consumption could be reduced by 44%. That's just one of the findings included in a new study by researchers from the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

The researchers used a powerful new modeling program, BEopt, to choose the most cost-effective package of measures designed to reduce the energy consumption of a new house by various percentages (see Table 1).

Although the intent of the study was to investigate ways to reduce peak utility loads, the researchers ended up looking at ways to reduce a home's total energy consumption, including all electrical loads and heating loads.

The study, "Program Design Analysis using BEopt Building Energy Optimization Software: Defining a Technology Pathway Leading to New Homes with Zero Peak Cooling Demand," was written by Ren Anderson, Craig Christensen, and Scott Horowitz. Anderson and Christensen are NREL researchers, while

Table 1—Measures Designed To Reduce Energy Use By 44%

Measure	Incremental Cost
Upgrade walls from 2x4 studs filled with R-13 batts to 2x6 studs filled with R-19 batts plus 2-inch foam sheathing	$1,748
Upgrade ceiling insulation from R-38 to R-60 fiberglass	$480
Air sealing improvements	$1,408
R-10 slab perimeter insulation	$1,371
Energy Star refrigerator	$178
Energy Star dishwasher	$89
Energy Star clothes washer	$563
Upgrade interior lighting to 100% CFL	$110
Upgrade air conditioner from 13 SEER to 15 SEER	$450
Credit from downsizing air conditioner to 2-ton unit	-$681
Upgrade gas furnace from 80% to 92.5% AFUE	$435
Credit from downsizing furnace to 50,000 Btuh	-$108
Upgrade gas water heater from 60% EF tank-style to instantaneous	$203
Relocate ducts to within the thermal envelope	$829
Solar hot water system (integrated collector and storage)	$2,654
Total	$9,729

Table 1. When this bundle of measures is installed in a new 2,592-square-foot two-story home in Sacramento, the homeowners will save 44% of source energy compared to a code-minimum house. The most cost-effective way to achieve energy savings beyond 44% is to include a photovoltaic (PV) system; in other words, a 44% energy reduction is as far as a builder can go without resorting to PV.

Scott Horowitz is a graduate student at the University of Colorado in Boulder. The paper was presented in August at a conference in Pacific Grove, California (the 2006 Summer Study sponsored by the American Council for an Energy-Efficient Economy).

A Hypothetical Sacramento House

To limit the study's complexity, the researchers examined a single hypothetical house: a new 2,592-square-foot two-story home in Sacramento, California. The house was assumed to have a slab foundation and an attached two-car garage. The house's window area was 18% of the floor area, with windows equally distributed among the outside walls. The house used natural gas for domestic hot water, space heating, cooking, and clothes drying.

The researchers assumed that natural gas is priced at $1 per Therm and electricity costs 12.7¢ per kWh. Future increases in utility costs were assumed to be no higher than the rate of inflation.

The computer modeling program used in the study, BEopt, was developed by NREL researchers in 2004 as a means of determining the least-cost path to zero-net-energy homes. According to Anderson, Christensen, and Horowitz, BEopt determines an optimum package of efficiency measures by performing a series of energy-performance calculations. "The sequential-search approach used by the analysis method involves searching all categories (wall type, ceiling type, window glass type, HVAC type, etc.) for the most cost-effective combination at each sequential point along the path to zero net energy," the researchers wrote. "Starting with the base-case building, simulations are performed to evaluate all available options for improvement (one at a time) in the building envelope and equipment. Based on the results, the most cost-effective combination is selected as an optimal point on the path and put into a new building description."

Incremental Cost to Achieve Various Savings Levels

The NREL researchers defined the base-case home as a code-minimum home—that is, a home barely complying with California's Title 24 energy code. An investment of only $5,000 in energy-efficiency measures beyond code minimum requirements resulted in source-energy savings of a whopping 40%; an investment of $15,000 yielded savings of 50%, and an investment of $25,000 yielded savings of 60%. Achieving any savings beyond 44% requires the use of photovoltaic (PV) modules. The inclusion of PV modules in a house using 60% less energy than the base-case house allows the house to achieve "zero peak cooling demand," since the energy produced by the PV system balances the air conditioner load under peak conditions.

Determining An Optimum Package Of Energy Upgrades

Adding energy-efficiency measures to a new home can reduce the total cost to the homeowner for utilities and mortgage payments compared to a code-minimum house—up to a point. As more and more measures are included, energy costs get lower and lower, until a point is reached that is optimal from a cost perspective. For the hypothetical house in Sacramento, this optimal investment occurs with measures designed to lower energy costs by about 35% (see Figure 6).

If the right measures are chosen, a house built to use 35% less energy than a code-minimum house can save homeowners about $25 per month, even considering the cost of the higher mortgage required to pay for the energy-efficiency measures. Beyond this optimal point, as further energy savings are achieved, the monthly costs to the homeowner for utilities and the mortgage begin to rise. Those who desire to lower energy costs by 50% will have to invest more than the optimum amount; but even at this higher level of investment, the homeowner's monthly mortgage and utility payments are still no higher than those for a code-minimum house.

For more information, contact Ren Anderson (ren_anderson@nrel.gov) or Craig Christensen (craig_christensen@nrel.gov).

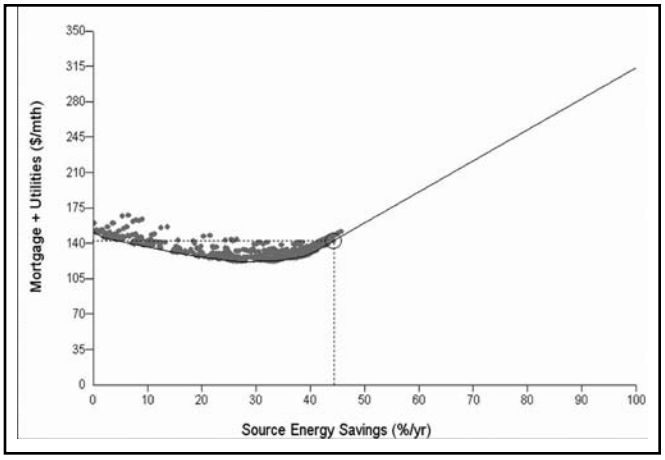

Figure 6. Researchers Ren Anderson, Craig Christensen, and Scott Horowitz label this graph the "least-cost curve." As energy-efficiency measures are added to the specifications for the Sacramento house, there is a drop in the homeowners' monthly utility costs plus the mortgage payments covering the added cost of the energy upgrades, until the "least cost" point is reached in the vicinity of 35% source energy savings. Further energy-efficiency measures beyond this point increase the total monthly costs to the homeowner.

NEW PRODUCTS

Tyvek ThermaWrap

DuPont has released a new housewrap, Tyvek ThermaWrap, described as an "insulating, breathable membrane" (see Figure 7). Although breathable membranes are nothing new, it takes chutzpah to call a membrane "insulating"—especially since the new housewrap is not much thicker than conventional Tyvek.

According to DuPont, ThermaWrap works "by shrinking thermal bridges"—whatever that means. After wading through the marketing material, it becomes clear that ThermaWrap's "insulating" properties derive from its low emissivity (or emittance). The company claims, "By replacing [ordinary] building wrap with Tyvek ThermaWrap—a low-emissivity membrane—in any wall system with a gap of at least ¾-inch between the framing and the siding, we create an effective thermal resistance (R-value) equal to R-2. The R-value created by Tyvek ThermaWrap helps to reflect the radiant energy that has accumulated in the wall sheathing back into the wall system so it is not released to the exterior."

What DuPont Doesn't Mention

There are at least two problems with DuPont's explanation. The first is that there is no "R-value created by Tyvek ThermaWrap." As Dave Yarbrough, a research engineer at R & D Services in Cookeville, Tennessee, explains, "The R-value of the assembly is due to the air space. The R-value of the product itself is negligible." The second problem with DuPont's explanation concerns information that DuPont fails to note: namely, that a ¾-inch air space already has a thermal resistance of about R-1, even when regular Tyvek is used. In other words, if ThermaWrap is used on a house with a ¾-inch continuous rainscreen, it may boost the R-value of the air space from about R-1 to about R-2.

Figure 7. Although DuPont touts Tyvek ThermaWrap as a "low-e" membrane, the emissivity of the product remains a closely guarded secret.

Since ThermaWrap is touted as a "low-emissivity membrane," those interested in quantifying the advantage, if any, of using ThermaWrap instead of regular Tyvek need to know whether ThermaWrap's emissivity differs from that of regular Tyvek. Surprisingly, however, DuPont fails to provide ThermaWrap's emissivity in the product specification sheet. When contacted by e-mail, Arturo Horta, DuPont's product manager for ThermaWrap, explained the omission this way: "We don't quote emittance values, since they mean nothing to builder or contractors. We always publish R-values since they are much more practical, useful, and understandable." In a follow-up e-mail from DuPont's public relations firm, representative Mike Touhill explained, "Arturo … has informed me that due to company policy he is not at liberty to reveal the actual emissivity number for Tyvek ThermaWrap." In other words, "It's low-e, but we can't tell you how low. Trust us." If DuPont's calculations for the R-value of an air space adjacent to ThermaWrap are to be believed, it can be inferred (from tables published in *ASHRAE Fundamentals*) that the product's emissivity is about 0.2.

Although Horta claims that "we always publish R-values," DuPont does not, in fact, list the R-value of ThermaWrap—apparently because the R-value of the product is so negligible that listing it would be embarrassing. Instead, DuPont trumpets the R-value of an air space adjacent to a layer of ThermaWrap, falsely implying that the thermal benefits of the air space's R-value are entirely due to the proximity of the ThermaWrap.

ThermaWrap's emittance may or may not be lower than that of ordinary Tyvek. According to Horta, it is not low enough for the product to qualify as a radiant barrier. (A radiant barrier is defined as a product with an emittance of 0.1 or less.) Nor does ThermaWrap meet the definition of a reflective insulation. (According to ASTM C168, ASTM C727, and ASTM C1224, a reflective insulation is defined as "a thermal insulation consisting of one or more surfaces having an emittance of 0.1 or less.")

Skating On Thin Ice

Any time a building product manufacturer attributes the R-value of a building assembly that includes an air

space to a single component of the building assembly, the manufacturer is skating on thin legal ice.

Although DuPont calls ThermaWrap an "insulating" membrane, in most applications it will perform about the same as housewrap. According to DuPont's marketing materials, "Tyvek ThermaWrap adds a low-emissivity ("low-e") surface that changes the dynamics of heat flow across the entire wall system, and dramatically helps improve the insulating value of the wall system." But any improvement in the insulating value of the wall system—an improvement that will almost never be "dramatic"—is only possible in a few wall assembly types. "To obtain the thermal value, it must be installed under brick or under a continuous rainscreen installation," admits Horta. "Under vinyl siding, it will have no thermal value, because there is no continuous air space." So much for changing the dynamics of heat flow across the entire wall system.

To promote its new housewrap, DuPont informs builders, "Nearly two-thirds of the total heat lost or gained through the building envelope occurs through radiant heat flow." But as Yarbrough notes, "It depends on where in the building envelope you are talking about. If you're talking about the heat flow from the siding to the exterior environment, that heat flow is primarily by convection. If you're talking about the heat flow through the gypsum wallboard, none of it is by radiation. If you're talking about the heat flow across an air space between the housewrap and the siding, then the radiation component might be in that ratio. But the statement is kind of deceptive, because it gives the impression that if you use this product, you will cut the heat flow through the wall by two-thirds, and that clearly isn't true."

High Permeance Is a Double-Edged Sword

DuPont cites ThermaWrap's high permeance (36 perms) as an advantage: "This [high permeance] is especially important … in hot, humid climates." But in a hot, humid climate, a high-permeance wrap is a double-edged sword: while it may permit the wall to dry to the exterior, it also allows solar radiation to drive exterior moisture into the wall cavity. In contrast, although a low-perm sheathing like polyisocyanurate may prevent a wall assembly from drying to the exterior, it also prevents inward solar vapor drive.

Builders interested in wrapping a house with a radiant-barrier product that is truly "insulating" should probably stick to foil-faced polyisocyanurate, which has a significantly lower emittance than Tyvek ThermaWrap. Moreover, polyisocyanurate, unlike ThermaWrap, has a non-trivial R-value; for example, ¾-inch-thick polyisocyanurate has an R-value of 5.4.

For more information, contact DuPont Company, 1007 Market Street, Wilmington, DE 19898; Tel: (800) 448-9835 or (302) 999-5965; Web site: *www.tyvek.com*.

Whole-House Electricity Monitor

Most off-grid homeowners monitor their energy use fairly closely, using meters like the Bogart TriMetric. Now a similar electricity monitor has been designed for grid-connected homeowners. The Energy Detective is a whole-house electricity monitor that displays real-time electricity use in kilowatt-hours (kWh) or dollars per hour. It also shows how much electricity has been used since the beginning of the billing period.

For motivated homeowners, the Energy Detective can be an important tool to help reduce energy use. The Energy Detective has two components: a transmitting unit mounted in the electrical service panel, and a receiving/display unit installed in a convenient location, such as the kitchen or living room (see Figure 8).

Toggling Through The Menu

Like many electronic devices, the Energy Detective's display is equipped with a minimum number of buttons; as a result, getting the unit to display the desired data is not particularly intuitive. By toggling through a menu, however, any homeowner capable of resetting a digital watch can learn how to get the device to display the following:

- Real-time electricity use in kW or dollars per hour;
- Amount of electricity used so far today, in kWh or dollars;
- Amount of electricity used so far this billing cycle, in

Figure 8. The Energy Detective's display unit can be plugged into any convenient electrical receptacle.

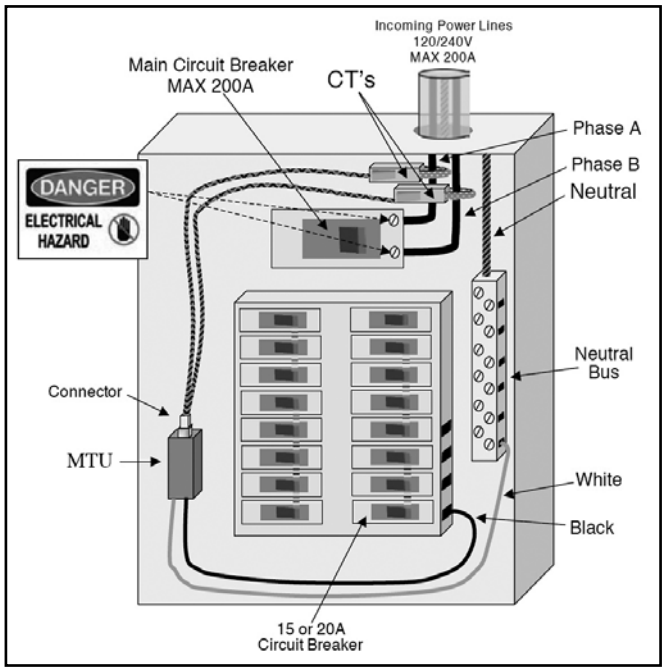

Figure 9. This illustration shows the location of the Energy Detective's measuring / transmitting unit (MTU). The two current transformers (CTs) must be clamped onto the incoming power lines.

kWh or dollars;
- Peak level of power used today (or this month), in kW or dollars;
- This month's projected electric bill, in kWh or dollars;
- Present voltage; today's low voltage; or today's high voltage.

The Energy Detective includes an alarm that can be programmed as a low-voltage alarm, a high-voltage alarm, or an alarm that goes off if the house exceeds a preset maximum level of kW usage.

For customers with time-of-use billing, the Energy Detective displays a flashing green LED to indicate when off-peak rates are in effect; a yellow LED to indicate peak rates; and a red LED to indicate critical peak rates.

Clamps and Wires

The Energy Detective's transmitting unit, a black box smaller than a pack of cigarettes, is installed in the electrical service panel (see Figure 9). The unit has two leads that must be connected to provide power to the unit; the black lead goes to a 15-amp or 20-amp circuit breaker, and the white lead goes to the neutral bus bar. The unit also has two clothespin-like current transformers that need to be clamped onto the main cables entering the service panel from the meter.

Tariff Flexibility

Because the Energy Detective transmits data through a home's AC wiring, the display unit is able to receive data once it is plugged into any outlet. However, the receiver must first be programmed with pertinent information, including the local rate schedule. Fortunately, the programming instructions for the Energy Detective are thorough and well written.

The Energy Detective fully accommodates a variety of electrical tariff schemes:

- Simple rate (e.g., 8.5¢ per kWh);
- Tiered rates (e.g., 8.5¢ per kWh for 0-500 kWh, 9.5¢ per kWh for 501-999 kWh, 10.5¢ per kWh for energy beyond 1,000 kWh);
- Time-of-use rates;
- Summer / winter rates;
- Fixed monthly charges (e.g., $12 per month for street lighting);
- Fuel surcharges or taxes (fixed fee or percentage);
- Any combination of the above.

According to the manufacturer, the accuracy of the Energy Detective is ±2%. The Energy Detective maintains programming, including time and date, in the event of a power failure. Model 1000—the basic model, designed to handle 200-amp residential service—can be ordered from the Energy Detective Web site for $140.

For more information, contact The Energy Detective, 44-G Markfield Drive, Charleston, SC 29407. Tel: (843) 766-9800; Web site: *www.theenergydetective.com*.

Two New Plastic Sill Pans

Since ***EDU*** last reviewed plastic sill pan flashings (see ***EDU***, July 2004 and October 2004), two more manufacturers, Dow and Marvin, have entered the market.

Dow Weathermate Sill Pan

The Dow Weathermate pan is a two-piece transparent sill pan flashing made of flimsy plastic. Each piece measures 32 inches long; allowing for a 4-inch overlap, the two flashing pieces will fit a rough opening up to 60 inches wide (see Figure 10). For wider windows, a third piece—created by cutting off the unnecessary corner—can be inserted between the corner pieces.

Sections of the Weathermate sill pan are attached to the rough opening with nails or staples. Seams between the Weathermate flashing pieces are designed to be sealed

Figure 10. The Dow Weathermate Sill Pan is a thin, transparent flashing that appears to be made of "blister pack" plastic.

Figure 11. The Marvin SillGuard (above) is far more rugged than the Dow sill pan. The flashing is sloped to the exterior; integral ridges keep the window frame above the drainage plane.

with tape; Dow recommends using Weathermate butyl rubber flashing tape.

The Dow Weathermate sill pan flashing includes an integral ⅜-inch-high back dam, a valuable feature. Unlike some other sill pan flashings, though, the Weathermate sill pan does not include an integral slope. Installers must therefore shim the rough sill for drainage before installing the Weathermate sill pan. The instructions note, "Weathermate Sill Pan works best when the window sill is sloped to the exterior. Shims, if necessary, should be placed underneath Weathermate Sill Pan."

When ***EDU*** asked Dow representatives what the Weathermate sill pan is made of—polyethylene? polypropylene? PVC?—they refused to answer the question. "This is proprietary information," said Jan McKinnon, a public affairs representative at Dow. The flimsy material appears to be "blister pack" plastic—the same material used to package small toys that are sold on cardboard rectangles. When stepped on, the plastic can be permanently creased, and it is possible to tear the material with one's bare hands. This product appears unlikely to withstand the normal rough handling that occurs on the typical job site. The Weathermate sill pan sells for about $5 each.

Marvin SillGuard

The Marvin SillGuard is a rigid polypropylene sill pan flashing that comes in three pieces: a left corner, a right corner, and a trimmable center section (see Figure 11). Using just the corner pieces, a rough opening up to 27 ½ inches wide can be protected. Using all three pieces, including the 48-inch-long center piece, the flashing can protect a rough opening up to 73 ⅜ inches wide.

Unlike the Weathermate sill pan, the Marvin SillGuard is a sloped flashing that directs water to the exterior, even when installed on a level rough sill. The flashing is much more substantial than the Dow product. It includes ridges that keep the window frame suspended above the draining surface of the flashing.

To leave enough room for a SillGuard pan, Marvin advises installers to size a rough opening ¼ inch higher than usual. The flashing pieces are designed to be nailed to the framing with 2-inch roofing nails. Unlike the Weathermate flashing, the Marvin SillGuard flashing does not include a back dam. (The SillGuard instructions advise installers to run a bead of caulk along the back side of the sill pan to form a site-built back dam.)

The joints between the sections of SillGuard pan flashing are designed to be sealed with construction adhesive. When asked how long Marvin expected a bead of construction adhesive to remain waterproof, John Kirchner, a public relations manager at Marvin, responded, "This is a question better asked of the adhesive manufacturer." (In any case, Marvin is not prone to bragging about product longevity; SillGuard comes with the following notice: "Your SillGuard rigid sill pan is warranted to be free from defects in materials for a period of 90 days." Imagine—almost three months.)

The Marvin instructions permit installers to use shims, if necessary, between the SillGuard flashing and the window. Marvin rejects the advice of ASTM E2112, the window installation standard that requires the use of caulk behind the bottom flanges of flanged

windows. In order to allow any moisture accumulating in the sill pan flashing to drain away from the building, Marvin advises omitting caulk under a window's bottom flange.

The SillGuard pan flashing is available in two depths: 4 9/16 inches for 2x4 framing, and 6 9/16 inches for 2x6 framing. The product is suitable for use with either doors or windows (except for bow or bay windows, of course).

For more information, contact:

Dow Building Materials, 200 Larkin Center, Midland, MI 48674. Tel: (866) 583-2583 or (989) 636-1000; Web site: *www.dow.com/styrofoam/na/weather/prod/wm_sill.htm*.

Marvin Windows, P.O. Box 100, Warroad, MN 56763; Tel: (888) 537-8266 or (218) 386-1430; Web site: *www.marvin.com*.

INFORMATION RESOURCES

Tax Credits For New Home Builders

A contractor who builds new energy-efficient homes can receive a federal tax credit of $2,000 per eligible home. To learn more about the tax credit, builders can visit an informative Web site maintained by RESNET, the national association of home energy raters and energy-efficiency mortgage lenders.

Some important tax credit details:

- The tax credit is available to contractors, not homeowners.
- To be eligible, a new home must be designed to use no more than 50% as much energy for space heating and cooling as a home that minimally complies with the 2004 Supplement to the International Energy Conservation Code.
- The amount of energy used for domestic hot water, lighting, and plug loads is irrelevant.
- The IRS has approved only four software programs for determining a home's eligibility: Builder Energy Solutions Calculator, EnergyGauge USA, Micropas7, and REM/Rate.
- To claim the tax credit, a contractor must complete IRS form 8908 (available online at *www.irs.gov/pub/irs-pdf/f8908.pdf*).

RESNET's Web page ("Frequently Asked Questions for Builders About the Energy Efficiency Tax Credits for New Homes") can be found at *www.resnet.us/taxcredits/faq-builders.htm*.

READERS' FORUM

RenewAire Stands Behind Its Products

Dear Editor,
EDU did an excellent job of laying out the long history and technological background on the subject of static plate ERVs ["Are ERV Cores Prone To Failure?," July 2006]. While I do not know of and so do not expect any reports [of core failures], please know that RenewAire stands behind our products and we will satisfy any customers' concerns or needs.

Douglas Steege
RenewAire
Madison, Wisconsin

Worthy of Attention

Dear Editor,
This is in response to the Editor's Reply to "Doom and Gloom to Liars," in the Readers Forum (June 2006).

In your reply you accurately describe Polar Industries as an expanded polystyrene (EPS) manufacturer. We do produce a variety of rigid EPS insulation products that may or may not be private labeled. P2000 is among them and is made to customer specification. Further, as you point out the R-value of EPS is around 4 per inch at 75 degrees Fahrenheit. This is widely accepted and easily referenced in ASTM C-578. Polar Industries has never made any claim to the contrary, and we generously regard your suggestion that we have as misguided and worthy of retraction.

On the other hand the marketers of P2000 have made claims about R-value performance that are much higher than those in C-578 and are rightly being challenged to prove it. While they do publish 75 degree Fahrenheit R-value numbers on their website, P2000's emphasis on in-field performance moves beyond the FTC's labeling requirements.

Specifically P2000's test methodology compares different insulation materials in side-by-side wall tests. Under this approach consumers have the informa-

tion to compare the actual performance of alternative designs in conditions that more closely describe the climate in their area. At a time when the floor of energy cost has shifted upward, their approach may be worthy of attention.

Paul Greenhalgh, sales manager
Polar Industries
Prospect, Connecticut

Editor's Reply

EDU agrees with Mr. Greenhalgh that it is appropriate to challenge the marketers of P2000 insulation to prove their inflated R-value claims, and that R. R. & D.'s test methodology is "worthy of attention."

EDU has no reason to doubt Mr. Greenhalgh's contention that Polar Industries is not responsible for the marketing materials used to promote P2000. Inasmuch as the reply in our June issue may have given some readers the impression that Polar Industries markets P2000, ***EDU*** offers an apology and hereby sets the record straight. To the best of ***EDU***'s knowledge, the marketing of P2000 insulation is managed not by Polar Industries but by R. R. & D. Enterprises of Rivière Beaudette, Quebec, Canada.

According to Mr. Greenhalgh, Polar Industries "produces" P2000. Does this mean that Polar Industries is the manufacturer of P2000? Or is R. R. & D. the manufacturer? Ultimately, such a determination is a matter for lawyers, not journalists. Moreover, the question of whether or not a manufacturer in Polar Industries' position bears any legal liability for marketing claims made by distributors of the insulation manufactured in its factory is also a matter best determined by lawyers.

If Polar Industries is, indeed, the manufacturer of P2000, certain provisions of the federal R-Value Rule apply; for example, section 460.13 of the R-Value Rule requires, "If you are a manufacturer, you must give retailers and installers fact sheets for the insulation products you sell to them." ***EDU*** telephoned Mr. Greenhalgh and asked whether he could send ***EDU*** a copy of the P2000 fact sheet. He responded, "We don't have a fact sheet for the product."

Blame the Insulation, Not the Roofing

Dear Editor:
Concerning the "White Roofing Causes Wet Insulation" article [June 2006]: White roofing does not *cause* wet insulation. In modern houses, moisture moving to a condensing surface through insulations and building systems incapable of resisting or dealing with that moisture movement causes wet insulation. It may be that white roofing exacerbates this reality by causing wider or longer temperature swings or by magnifying some other very interesting micro force, but this is not the essence of the problem. Essentially air-filled building cavities delivering moisture to cold surfaces below the dew point *is* the problem.

My bet is that all the roofs of the described construction, regardless of the color of their covering, have some evidence of moisture having condensed in them—just not at the levels or frequency that drive to failure. Why else would we have made a practice of venting attics and cathedral roofs?

The refrigerator manufacturers understood the problem, and its solution, over forty years ago when they abandoned glass-fiber insulation in favor of closed-cell polyurethane foam (PUF). If you go to any reefer manufacturer at the Builders Show and ask for a glass-fiber insulated unit today, you will be laughed off the floor or looked at quizzically. In reefers (and controlled atmosphere storage of all types), closed-cell PUF gets the air-carrying moisture out of the equation and its closed-cell structure deals with diffusion vapor drives as well, regardless of the particular climate and which direction the drive may reverse to between day and night or season to season.

It's fun to sleuth building envelope failures and to be the one who comes up with the most reasonable explanation—many of those quoted in the article, and many others besides, are well known for doing just this. However, the main explanation for all of it is that the building industry continues to predominately use fiber insulation products and systems that are forty years obsolete. Go figure.

I think it's "marketing science" that perpetuates the obsolescence. Intelligent application of building science ought to tell the difference. [Edited for length]

Neal Ganser, president
Corbond Corporation
Bozeman, Montana

[Editor's note: Corbond Corporation is a manufacturer of products used to install sprayed-in-place polyurethane foam insulation.]

BACK PAGE

Revisiting Seasonal Solar Heat Storage

A year ago, ***EDU*** reported on two new Colorado houses with solar hot water systems designed for seasonal heat storage (see ***EDU***, September 2005). Ron Larson of Golden, Colorado, built a house with five solar collectors and an 11,000-gallon storage tank, while Eric Doub of Boulder, Colorado built a house with twelve solar collectors and a 6,000-gallon storage tank.

Recently the two owners were asked how their heating systems performed over the first winter. "It didn't work well enough," Larson told ***EDU***. "Because I've been so busy, I haven't collected as much data as I should. But the temperature in the storage tank never got as high as I hoped. I think it only reached 135 degrees or so in late fall. Basically the temperature was diminishing more rapidly than it could be maintained, so I've ordered four more solar panels. I plan to install the new panels at a steeper angle, for better winter performance, so the snow slides off faster. I think I lost six or eight days of sun last winter due to snow on the panels."

Eric Doub's report was more positive. "We were warm and toasty all winter," Doub told ***EDU***. "The storage tank temperature was up to 168 degrees in January. The longest stretch of cloudy weather was in mid-February, when we got four cloudy days in a row. Because of the passive solar design, we used the radiant floor heating system only eight or ten times the whole winter."

Doub's biggest headache has been his storage tank. Worried about leaks, he decided at the last minute to change his original tank design (a concrete tank coated on the inside with a spray-on truck-bed liner). For increased waterproofness, he installed a layer of 40-mil EPDM rubber on top of the spray-on liner. Soon after the tank was filled with water, however, it began to leak, so Doub drained the tank and removed the EPDM.

The useless truck-bead liner left a bumpy surface on the inside of the tank. To create a smoother surface, Doub installed a layer of ½-inch polyisocyanurate insulation on the tank's walls and floor, covering the rigid foam with two layers of 60-mil EPDM. "We spent about $10,000 for the tank," said Doub. "If I had to do it again, I would not install the type of tank we have in our basement. It's a potential Poseidon Adventure."

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