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INDUSTRY NEWS

An Expanding EcoVillage

EcoVillage in Ithaca, New York, is a co-housing community that uses green building principles to guide its construction projects. The nonprofit community owns 172 acres, of which 90% consists of woods, wetlands, and agricultural land protected from future development. EcoVillage will eventually consist of five neighborhoods, two of which have already been built. The first neighborhood, nicknamed FROG (for "First Residents Group"), was completed in 1997. The Second Neighborhood Group (SONG) has been under construction for the last two years and is now almost complete.

Co-housing is a type of clustered housing that usually includes a common building shared by all community members. The co-housing movement, which began in Denmark, is an attempt to base housing design on social cooperation, ecological sustainability, and resource efficiency.

EcoVillage's First Neighborhood

During the years of planning meetings preceding the start of construction, the founding members of EcoVillage agreed that their new homes should be built with a high level of energy efficiency. EcoVillage's first neighborhood consists of 30 units (15 duplexes) measuring between 900 and 1,700 square feet each. The neighborhood also includes a common house with a dining room, kitchen, children's playroom, music room, crafts room, and laundry. The common house is heated by a pond-source heat pump.

EcoVillage's FROG buildings have tight, well-insulated shells incorporating thick walls (2x6 studs strapped with interior 2x2s), R-40 ceilings, and triple-glazed windows (see Table 1, page 4). These features helped reduce the homes' heating loads below the level of the domestic hot water loads.

The 30 housing units were grouped into four clusters (three clusters of eight units and one cluster of six units), with a pair of natural-gas boilers serving each cluster. Boiler water circulates in an insulated piping loop located in a buried conduit (18-inch-diameter sewer pipe). Each house has a fan-coil unit to permit the heat to be distributed through ductwork.

Although the FROG buildings have very low heating loads, the heating system includes some inefficiencies.

In This Issue

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Figure 1. Many residents in the first neighborhood at EcoVillage in Ithaca, New York, have erected trellises to reduce the amount of solar gain through their south-facing windows. [Photo credit: Jim Bosjolie]

"The advantage of the mini-district system is that should any new technology come along, like fuel cells, you can retrofit several houses with one change-out," says Jon Harrod, general manager of Performance Systems Contracting and the designer of the heating systems installed in EcoVillage's second neighborhood. "The disadvantage is that your heating plant is outside the thermal envelope, and you have a lot of distribution losses through the piping."

To provide domestic hot water, each housing unit has an indirect water heater heated by boiler water through a heat exchanger. Mechanical ventilation is provided by timer-controlled bathroom exhaust fans, with measured levels of fresh air introduced through the HVAC ductwork.

Lessons Learned

As with any construction project, hindsight has provided perspective on possible design improvements (see Figure 1). "The design process didn't have energy modeling built into it soon enough, and there were some design features set up in the early stages that were too expensive to alter later," notes energy consultant Gregory Thomas, the designer of the first neighborhood's heating system. "The biggest thing was all the south-facing glass, which was included for architectural reasons—the architect was going for a certain look and feel. The amount of south-facing glass causes some performance problems. When it gets cold outside the glass sheds a lot of cold air, even with the triple-glazed windows. Spring overheating is another issue, and over time a number of residents have set up trellises in front of the units to provide shading."

One of the most important tasks addressed during the planning meetings for EcoVillage's second neighborhood was the development of default specifications for the new buildings. Early in the planning process, members decided that all of the buildings must at a minimum meet the requirements of the Energy Star Homes program—a program that was in its infancy in 1997, when the first neighborhood was completed.

ICFs and SIPs

Instead of 2x6 walls and triple-glazed windows, the second neighborhood members decided to specify structural insulated panel (SIP) walls and double-glazed windows. "We decided it was difficult to justify the extra cost of triple-pane windows," says Harrod, a member of the committee that developed the default specifications. "We did an economic analysis and found that the savings from the triple-pane glass compared to double-pane low-e glass were marginal."

SONG members have decided to allow flexibility in the application of the neighborhood's design requirements. "Most people went with the recommended set of

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guidelines, but a couple of people wanted to frame with real wood," says Harrod. "They were worried about offgassing from the SIP panels, so they chose stick-frame construction with damp-spray cellulose or Miraflex fiberglass insulation." One of the new houses has straw-bale walls.

Most of the SONG buildings, unlike the FROG buildings, have full basements (see Figure 2). The default specs call for below-grade walls to be built of insulated concrete forms (ICFs). "I'm very happy with the ICF foundations," says Harrod. "We haven't had any problems with them. We paid a lot of attention to the exterior foundation details. We've got footer drains and gravel backfill, and a bituminous membrane over the ICFs. The exterior is as waterproof as we could make it. It's one thing we didn't want to skimp on, because our basements are all finished and fully lived in. "

Figure 2. Most of the houses in EcoVillage's second neighborhood have full basements with insulated concrete form walls.

Figure 3. A variety of incentive programs in New York state reimburse between 50% and 75% of the installation cost of photovoltaic modules, and many of the new EcoVillage homes include large photovoltaic arrays.

Smaller Boilers

Unlike the first neighborhood, the SONG buildings use one boiler per duplex. "We went with smaller boilers," says Harrod. "We decided to bring the boilers inside the thermal envelope, cutting way down on the piping heat losses. Our guess is that doing that will save about twenty percent in fuel consumption, plus the additional savings associated with going to condensing boilers." Instead of distributing the heat through ductwork, the new buildings use a combination of radiant floors and fin-tube baseboard units.

SONG residents are allowed to burn firewood, but only on a provisional basis. "Since this is a high-density development, and since many residents have asthma or multiple chemical sensitivity, we decided to take a cautious approach to using wood stoves," says Harrod. "We mandated that houses with wood stoves need to have some other kind of heat, so that if there is ever a problem we could shut down use of wood heat."

New York state offers generous incentives for the installation of photovoltaic (PV) modules, and the residents of the second EcoVillage neighborhood have embraced solar electricity in a big way (see Figure 3). Many of the new houses include large (between 2 kW and 2.5 kW) PV arrays sized to meet the residents' full annual electrical budget.

Learning Curve

Since many of the SONG residents are owner/builders, some of the construction crews were learning on the job. "On air-sealing details, we went in with the right knowledge and the right intentions, but didn't exactly achieve our goals," says Harrod. "I would have liked to have had the contract to air-seal all the houses, but the air sealing was done by site crews who are basically untrained labor. As a result we ended up with a fairly wide range of blower-door readings, with the best houses being under 500 cfm at 50 Pascals, and the leakier houses being in the 1,200 cfm range."

All of the homes in the second neighborhood are expected to be completed by the end of 2003; nineteen of the new homes are already occupied. One SONG resident, Francis Vanek, reports that the energy-efficiency features of his new home are performing well. In recent months his family has been consuming only 180 kWh of electricity per month, and Vanek anticipates that his 2.2-kW PV system will produce as much electricity in a year as the family uses. Last winter, his 2,250-square-foot house had a natural gas bill of about $100 per month (for heat, hot water, and cooking), while his parents, who also live in Ithaca, were paying about $300 per month. One of his few complaints concerns his attic-mounted energy-recovery ventilator, which is louder than expected.

EcoVillage is a thriving community and a successful example of energy-efficient clustered housing. "I don't like to call this co-housing—that's the social aspect of this," says Greg Thomas. "But all of the physical benefits of clustered housing occur whether or not it is set up as co-housing. You don't have to buy into that social arrangement."

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Table 1—Construction Specifications for EcoVillage Ithaca

	First Residents Group (FROG)	Second Neighborhood Group (SONG)
Foundation	Crawlspace (walls and slab floors insulated with 2 inches of rigid foam)	Eco-Block insulated concrete forms
Walls	2x6 walls with 2x2 interior strapping; cellulose insulation	6-inch Thermapan SIPs; alternate construction methods must be R-26 minimum
Windows	Accurate Dorwin triple-pane	Andersen double-pane low-e argon
Attic insulation	R-40 cellulose	R-50 cellulose
Heating system	Vaillant 83% AFUE 200,000 Btuh natural gas cast-iron boilers.	Munchkin 92% AFUE natural gas condensing boilers from Heat Transfer Products
Heat distribution	Fan/coil units and hot-air ductwork, with some hydronic baseboard under windows	Basement radiant slabs with hydronic baseboard elsewhere
Domestic hot water	Each unit has a 20- or 30-gallon indirect water heater warmed by boiler water	Each unit has an indirect water heater
Ventilation	Exhaust fans in bathrooms; fresh air intake connected to return air ductwork	Exhaust-only ventilation using a Panasonic fan on a 24-hour timer; available alternate is the RenewAire energy recovery ventilator
Air leakage	2.0 to 2.5 ac/h at 50 Pascals	Varies

Table 1. The two neighborhoods of the EcoVillage co-housing community in Ithaca, New York, were built at different times and have different construction specifications.

Simplifying the IECC

The Code Development Committee for the International Energy Conservation Code (IECC) has substantially approved a proposal for a sweeping simplification of the IECC. The September 12 vote, a key step in the process leading towards changing the code, occurred in Nashville, Tennessee, during the annual Code Development meeting of the International Code Council (see Figure 4).

The proposal to simplify the IECC, formally known as Proposal EC48, was submitted by the US Department of Energy (see ***EDU***, December 2002 and June 2003). The DOE proposal also included proposed changes to the energy section of the International Residential Code (IRC); these changes, like the IECC changes, were approved by the committee. Both the IECC and the IRC include residential energy sections, and the intent of

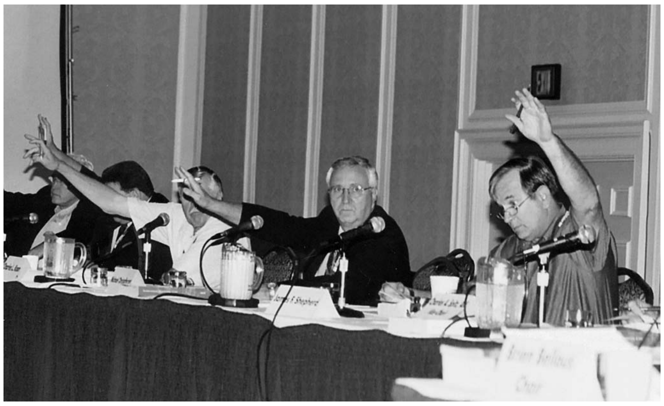


Figure 4. The code development committees of the International Code Council met in Nashville, Tennessee from September 5 to 14, 2003 to vote on a variety of proposed code changes.

the proposal was to simplify the two codes in a consistent manner, keeping the two codes aligned.

Adopting the reasoning of the drafters of the proposal, the committee reported, "Simplifying the requirements will hopefully improve and make the requirements easier to understand and also enforce. By making the code easier to apply, it is hoped that the result will be more complying buildings which will therefore improve energy conservation. … One of the primary things which makes this proposal easier to apply than the existing provisions is the elimination of the window/wall ratios."

Approved As Modified

In Nashville the committee listened to three and a half hours of public discussion and debate. The committee members then made several modifications to the original proposal before voting to approve Proposal EC48 as modified. Most of the approved modifications result in slightly increased stringency.

"I think it was good debate," said Jay Woodward, a senior staff architect at the ICC. "People were definitely in favor of the simplification—that was the big thing. I think people were amazed that it went through. We all saw the forest, even though there were individual trees that some people wanted to attack."

The committee approved the following modifications to the original DOE proposal:

- The proposed tables of default U-factors and default solar heat gain coefficients (SHGCs) for windows lacking a National Fenestration Rating Council label were deemed to be too streamlined. Instead of the proposed tables, the committee voted to substitute the longer default tables from the current IECC. According to the committee's report, "the original proposal was felt to be too much of an oversimplification."
- The proposal to permit HVAC system tradeoffs—for example, to allow a builder to omit basement insulation in exchange for inclusion of a SEER 13 air conditioner or an AFUE 92 furnace—was eliminated. The committee's report noted, "Concern was … expressed regarding the trade-off of long-term envelope performance versus [the] shorter life of equipment. Additionally, it was felt that many of the items which tradeoffs were being given for are essentially the current common practice and therefore no real gain is being obtained in order to trade."
- In some climate zones, the minimum insulation levels for wood-frame walls in the prescriptive table were increased (for example, from R-13 to R-15 in Zones 3 and 4, and from R-19 to R-21 in Zones 5 and 6).
- In some climate zones, the maximum fenestration U-factors in the prescriptive table were changed (for example, from 0.8 to 0.75 in Zone 2, and from 0.6 to 0.65 in Zone 3).
- In zones requiring more than R-30 ceiling insulation, the proposal to permit the use of only R-30 in sloped ceilings with rafters too small to accommodate the required level of insulation was eliminated. The committee reasoned that the modification "prevents people from intentionally building an assembly which they cannot fit enough insulation into and therefore permitting them the reduction to R-30."
- In cold climate zones, the committee changed the maximum permitted window U-factor when making trade-offs from 0.55 to a more stringent 0.40.

Proposed IRC Changes

Most of the debate in Nashville concerned proposed changes to the IECC. As for the DOE's proposed changes to the IRC, the committee approved the changes with few modifications. As approved, the IRC changes include:

- Unvented crawlspaces are permitted with the following requirements: the earth must be covered with a continuous vapor retarder with sealed joints, and the vapor retarder must be sealed to the crawlspace stem wall. Unvented crawlspaces must include either continuously operating mechanical exhaust ventilation (at a rate of 1 cfm per 50 square feet of crawlspace) or a grille providing conditioned supply air (at a rate of 1 cfm per 50 square feet of crawlspace) and a return-air pathway to the common area.
- Unvented conditioned attics are permitted if the insulation is air-impermeable and installed in contact with the underside of the roof sheathing. Moreover,

the ceiling below the attic floor must not include a vapor retarder. If asphalt shingles are used above such an attic in a warm humid climate, then a vapor retarder must be installed between the shingles and the roof sheathing. This last requirement is intended to address the problem of inward solar vapor drive (see ***EDU***, January 2003).

Steps Ahead

The changes to the IECC and the IRC approved by the Code Development Committee have been released for public comment until January 14, 2003. In April, all public comments will be published in a document called the Final Action Agenda.

On May 17, 2004, the ICC plans to meet in Overland Park, Kansas for another public hearing on the changes. After discussion by all interested parties, a final vote on the changes will be made, with the voting restricted to code officials. Although code officials can override the committee's endorsement, such vetoes are rare. If approved in Overland Park next May, the code changes will be incorporated into the 2006 editions of the IECC and IRC.

Simpler Codes Mean Easier Compliance

Among those attracted to the code-simplification bandwagon is Christopher Mathis, president of MC Squared in Burnsville, North Carolina, and a member of the IECC Code Development Committee. "I can't speak for the committee, I can only speak for me," says Mathis. "But from my perspective, this is one of the most dramatic and significant improvements to the energy code in decades. While it's not perfect, it creates an entirely new platform from which we can evaluate a building's energy performance and more easily determine compliance with the code. I applaud DOE in their efforts; they spent a lot of time working on this. While I disagree with some of the pieces of it, on the whole their approach was elegant and simple. This will get more people to comply and will make the code easier to enforce, and as a result we will get more energy savings."

For further information on the adoption of Proposal EC48, see the ICC's *Report of the 2003 Public Hearings* at *www.iccsafe.org/cs/codes/2003-04cycle/ROH/ROH_IECC2003.PDF*.

Streamlining ASHRAE's Residential Energy Standard

Responding to criticism that their residential energy-efficiency standard is cumbersome and difficult to use (see ***EDU***, June 2002), the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) recently released an addendum to the standard for public review. The addendum amounts to a significant overhaul of the little-used standard.

ASHRAE's Standard 90.2, "Energy-Efficient Design of Low-Rise Residential Buildings," was last updated in 2001. According to the ASHRAE notice accompanying the release of Addendum 90.2i, "This proposed addendum responds to the perception by many users that the current standard is too design-intensive and complex for simple structures." The proposed addendum would make the following changes to the standard:

- Commentary and non-enforceable language would be removed and replaced with mandatory language.
- 45 tables and figures would be replaced with two tables.
- The standard would adopt the eight simplified climate zones developed by the US Department of Energy as part of their proposal to simplify the International Energy Conservation Code (see the previous story).
- Although the standard would still require calculation of a building's window/wall ratio, the procedure for calculating envelope trade-offs would be simplified by eliminating the need to specify window area by orientation.

According to Steve Skalko, the manager for regional codes at the Portland Cement Association and the chair of the ASHRAE 90.2 committee, "The complexity of the document has clearly been a stumbling block to its acceptance, so with our improvements we hope that Standard 90.2 will be seen as an acceptable alternative to the IECC provisions."

In another development, ASHRAE recently signed a partnering agreement with the National Fire Protection Association (NFPA) to reference Standard 90.2 in the NFPA consensus code set. Along with Standard 90.1 (ASHRAE's energy-efficiency standard for commercial and high-rise buildings), Standard 90.2 will comprise the energy-code portion of the NFPA 5000 Building Code.

NFPA codes continue to come under fire from proponents of the International codes developed by NFPA's direct competitor, the International Code Council (ICC). A recent flare-up of the code wars occurred in California, where the July 29 decision by the California Building Standards Commission to adopt the NFPA 5000 Building Code was greeted by a storm of protest from pro-ICC architects, builders, and building officials.

NEWS BRIEFS

ATLANTA, GA—Appeals attempting to overturn the approval of Standard 62.2, the new residential ventilation standard developed by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), have been rejected by ASHRAE's board of directors. With the resolution of these appeals, Standard 62.2 is now an official ASHRAE standard. Although model building codes do not yet reference ASHRAE 62.2, the publication of the standard merits the attention of builders concerned with avoiding indoor-air-quality litigation.

WASHINGTON, DC—Recently built houses consume more energy than older homes, according to statistics compiled by the Energy Information Administration (EIA) of the US Department of Energy. Houses built between 1990 and 2001 consume an average of 92.7 million BTUs per year, significantly more energy than houses built during the previous three decades. The average annual energy consumption is 86.4 million BTUs for houses built in the 1960s, 78.5 million BTUs for houses built in the 1970s, and 79.3 BTUs for houses built in the 1980s. The most likely reasons for the deteriorating energy performance of US homes are the increased size of homes and appliances and the increasing popularity of air conditioning. The EIA's *Residential Energy Consumption Survey* is posted on the Web at *www.eia.doe.gov/emeu/recs/recs2001/detail_tables.html*. According to another recent EIA report, *Annual Energy Review 2002*, residential energy use in the US increased 3.4% in 2002 compared to the previous year. Details can be found at *www.eia.doe.gov/emeu/aer/contents.html*. Finally, a third EIA document, "Emissions of Greenhouse Gases in the United States 2002," reports that US greenhouse gas emissions increased 0.5% in 2002, bringing the increase in this country's greenhouse gas emissions since 1990 to 16%. For the full report, visit *www.eia.doe.gov/oiaf/1605/ggrpt/index.html*.

WASHINGTON, DC—Green design features are a cost-effective investment, according to a new study by the Capital E Group. The authors of the study, *The Costs and Financial Benefits of Green Buildings*, examined data on one hundred green buildings and concluded that the financial benefits of green features are ten times their incremental cost. The savings tallied in the report include benefits to building owners (lower costs for energy, water, and maintenance) and benefits to society (lower environmental costs). The report is posted on the Web at *www.usgbc.org/LEED/Project/project_list.asp*.

SEATTLE, WA—Efficiency Services Group (ESG) and HomeStreet Bank have teamed up to offer mortgages for energy-efficiency improvements to Seattle-area home buyers. The program, called Mortgage Options for Resource Efficiency, allows borrowers to add up to $4,000 to their home mortgage to finance investments in insulation, air sealing, duct sealing, efficient lighting, or energy-efficient appliances. To be eligible for the mortgage, borrowers must agree to have a home energy audit performed by an ESG specialist. More information is available from the Efficiency Services Group at (866) 784-5606 or *www.moreprogram.com*.

LONDON, UK—Global warming is currently responsible for about 160,000 deaths a year, according to a World Health Organization study by Professor Andrew Haines of the London School of Hygiene and Tropical Medicine. As reported by Reuters News Service, the Haines study concludes that tens of thousands of Third World deaths from malnutrition, diarrhea, and malaria can be traced to floods and droughts caused by global warming.

SACRAMENTO, CA—Before leaving office, outgoing Governor Gray Davis signed a bill, AB 1685, extending California's incentive program for the installation of photovoltaic (PV) modules until January 1, 2008. Had Gray failed to sign the bill, the PV incentive program administered by the California Public Utilities Commission would have expired at the end of 2003. The cost of an additional four years of PV rebates is estimated at $500 million.

WESTMINSTER, CO—A Habitat for Humanity house built in cooperation with the National Renewable Energy Laboratory (NREL) has won the 2003 Energy Star New Millennium Builder Award. The 1,425-sqare-foot house at 3520 Apple Blossom Lane in Westminster has a HERS rating of 95.9. The house boasts Icynene-filled 2x6 exterior walls and interior radiant partitions concealing hydronic heating tubes installed between knee-height and neck-height. The roof sports collectors for a drain-back solar hot-water system and 1.8 kW of photovoltaic modules. Employees from NREL were among the many volunteers who helped build the house..

WASHINGTON, DC—The US Department of Energy (DOE) has awarded grants totaling $20.4 million to 13 research projects aimed at increasing the energy efficiency of buildings. Among the funded areas of research are improvements in LED lighting (Cree Lighting), new phosphor coatings for fluorescent lamps (General Electric Global Research), improved aerogel window insulation (Aspen Aerogels), and smart windows (Rockwell Scientific and SAGE Electrochromics).

NORWALK, CT—According to a study by the Consortium of Advanced Residential Buildings, pressurizing ceiling cavities with interior air at a rate of 0.5 cfm per square foot during hot weather can eliminate the heat gain through R-19 attic insulation. To achieve the same effect, only 0.25 cfm per square foot is necessary with R-38 attic insulation. The research, which is funded by the California Energy Commission and the Building America program, is looking into the question of whether pressurizing ceilings improves the performance of evaporative cooling systems (see ***EDU***, May 2003).

CHICAGO, IL—A non-profit housing developer, Claretian Associates, has announced the opening of a development of duplexes and single-family homes called New Homes for South Chicago III. The $155,000 homes include R-24 walls, R-42 roofs, and AFUE 92.5% furnaces. Twelve of the homes will include 1.2-kW photovoltaic systems. Among the sponsors and consultants working on the project's energy-efficiency details are the Partnership for Advanced Technology in Housing; the Zero Energy Homes Program of the US Department of Energy; and Steven Winters Associates of Norwalk, Connecticut.

OCEANSIDE, CA—The home energy rating industry will celebrate its twentieth anniversary in 2004. A press release from the Residential Energy Services Network (RESNET) dates the birth of the industry to 1984, when the Energy Rated Homes of America program got off the ground in Alaska, Arkansas, and Vermont. The industry now boasts 4,000 certified raters in all fifty states.

MINNEAPOLIS, MN—The most enduring thermostat design in the world, the Honeywell Round, is now fifty years old. The simple and elegant device marrying a bimetal coil to a mercury switch was introduced in 1953.

NEW YORK, NY—A company called Rentricity has developed small turbines designed to generate electricity from the flow of water through water supply pipes. The company hopes to market the turbines to owners of high-rise buildings. The turbines, called "Flow-to-Wire devices," harvest surplus energy from over-pressurized water mains. Rated at 20 kW to 100 kW, the turbines function like pressure-reduction valves, with the added benefit of electricity production. For more information, contact Rentricity at (212) 334-5434 or *www.rentricity.com*.

COLOMBO, SRI LANKA—In Sri Lanka, where 41% of households live off the electrical grid, over 20,000 customers have purchased photovoltaic (PV) systems from Shell Solar Lanka. Dinukh Fernando, general manager of Shell Solar Lanka, said, "People always say that the big improvement in their lives is having light at the flick of a switch compared to kerosene, which is very messy and fussy," according to a news article on Solarbuzz.com, a solar energy Web site. Fernando says that he expects his PV sales to grow by 40% this year.

JUST BECAUSE A QUESTION IS FREQUENTLY ASKED DOESN'T MEAN THERE'S AN ANSWER—"Frequently Asked Questions About the Great Stuff Family of Products. Q. How do I get Great Stuff out of Clothing? A. Polyurethane foam cannot be removed from clothing." [From the Dow Chemical Web site at *www.dow.com/greatstuff/faq/*]

RESEARCH AND IDEAS

New Test Methods for Weather-Resistive Barriers

Builders trying to choose between housewrap, Grade D building paper, and asphalt felt—products collectively known as weather-resistive barriers, or WRBs—are often buffeted by conflicting information and contradictory urban myths. To separate fact from fiction, several researchers have hoped to develop laboratory tests to compare the performance of these products (see ***EDU***, August 2003).

The latest researcher to wade into this thicket is Mark Bomberg, a research professor at Syracuse University and an adjunct professor at Concordia University in Montreal. After spending months evaluating all of the various standard methods used to test WRBs, Bomberg has concluded that these tests aren't worth much. Since existing standard tests, including the boat test (ASTM D779) and the water-column test (AATCC 127-1985), "do not yield precise information," according to Bomberg, he proposes replacing the currently used tests with two new tests, the modified inverted cup (MIC) test and the liquid penetration resistance (LPR) test.

Several of the existing standard test methods examined by Bomberg gauge water transport across a tested membrane. But two transport mechanisms occur during these tests—vapor transport and liquid transport—and the test procedures fail to distinguish between the two mechanisms and fail to identify the ratio between the two mechanisms.

When it comes to advice to builders, Bomberg echoes the conclusions reached by Achilles Karagiozis, the Oak Ridge National Laboratory scientist who studied wall failures in Seattle: two layers of WRB are better than one (see ***EDU***, February 2003).

The Boat Test

The boat test (ASTM D779) calls for a sample to be folded into the shape of a boat and floated in water; an observer then measures the time required for water to penetrate the sample and change the color of a moisture-sensitive indicator dye. Determining the moment when the dye changes color depends on the judgment of the observer, Bomberg notes, and in some conditions vapor in the air can contribute to the color change. Moreover, the procedure does not address several potential problems, including uneven distribution of the indicator dye, crumpling of the membrane as the boat is folded, and the possibility of air pockets under the boat. Bomberg concludes that the boat test is "only suitable for quality control during manufacturing but inappropriate for evaluation of materials."

The Water-Column Test

Another commonly used test is AATCC 127-1985, also called the hydrostatic pressure test or the water-column test. To conduct the test, a sample of material is used to seal the bottom of a vertical tube. Water is added to the tube at a steady rate until moisture penetrates the sample; at that point the height of the water column and the elapsed time are recorded.

Although many housewrap manufacturers use the results of water-column tests to promote their products, the test conditions include hydrostatic pressures in excess of those seen in the field. "The maximum water-column test is very good for characterizing the pore size of all polymeric fiber membranes," says Bomberg. "But what is the value to the user? This test classifies one type of material, but it does not give me relevance for performance."

Ponding Test

Bomberg considered the usefulness of the ponding test—a method developed by the Canadian Construction Materials Centre (CCMC) as part of its *Technical Guide for Breather-Type Sheathing Membranes*—and noted that, in some respects, it is "reasonable" and "practical." Although the ponding test is not a published consensus document, it is used by the CCMC to evaluate WRBs. The test requires a membrane to retain one inch of water for at least two hours. But because of the difficulty of determining the precise time when three water droplets are visible on the underside of the membrane—a requirement of the test protocol—Bomberg concluded that "the test requires improvement."

The Modified Inverted Cup test

After reviewing all of the relevant existing test methods, Bomberg proposes two new tests for the evaluation of WRBs. The first of these, the "modified inverted cup" (MIC) test, is a modification of an existing ASTM method called the inverted cup test.
According to Bomberg, the Achilles heel of the existing ASTM method is the fact that it fails to specify the static pressure (depth of water) to be used. "The ASTM method specifies the use of water, but we don't know if it is one millimeter or one hundred millimeters," notes Bomberg.

Bomberg proposes modifying the ASTM method by specifying the use of 25 millimeters (about one inch) of water. To perform the test, the water is placed on top of the membrane being tested, while a frequently changed desiccant is placed below the membrane. Using a 25-millimeter depth of water "provided the maximum practical level of hydrostatic pressure"—namely, 250 Pascals. The contrast between the conditions on either side of the membrane—one side flooded at 100% RH, and the other side exposed to extremely dry air at close to 0% RH—corresponds, in Bomberg's phrase, to "the worst-case condition" likely to be faced by a WRB. The MIC test, Bomberg maintains, is a useful way to measure water vapor permeance.

Liquid Penetration Test

Bomberg proposes using a second test, the liquid penetration resistance (LPR) test, to supplement the MIC test. In the LPR test, the membrane is exposed to water on both sides. The top of the membrane is flooded and is exposed to 250 Pascals of pressure, while the bottom of the membrane is also wet and is exposed to 500 Pascals of pressure. The difference in pressure pushes water upward through the membrane being tested, and the flow from one side of the membrane to the other is measured.

The LPR test measures the performance of a WRB under different conditions than the MIC test. "The builder needs to know how the membranes will perform when they are wet on both sides," says Bomberg. "The liquid penetration resistance test has water on both sides, under conditions of a one-inch hydrostatic water pressure difference. The test measures how long the membrane will withstand this condition before the liquid goes through. There was no other test that would discriminate for this."

Moisture Flux measurement

In evaluating WRBs, Bomberg also praises the usefulness of moisture flux (MF) measurements. "Moisture flux is not a standard test, it is a measurement," says Bomberg. A moisture flux measurement uses plywood or OSB to test the effects of penetrations (nails or staples) on moisture transmission through a WRB. "Total moisture transfer from the water to the substrates such as OSB or plywood was measured with [the] MF method," Bomberg wrote. "This method is somewhat arbitrary because it includes combined liquid and vapor phase transport and the results depend on the hygric properties on the substrate … Nevertheless, this was the only method which allowed assessing the effects of mechanical penetrations."

Putting Membranes to the Test

After evaluating existing test methods and developing his new test methods, Bomberg used three methods (MIC, LPR, and MR) to test asphalt-impregnated paper membranes (asphalt felt and Grade D papers), perforated plastic housewraps, and non-perforated plastic housewraps. (Some housewraps, like Barricade and Typar, are perforated, while others, like R-Wrap and Tyvek, are non-perforated.) The tests were performed under a variety of circumstances, including when the membranes were penetrated by nails or staples; after the membranes were exposed to the weather for several months; and using water mixed with surfactants (see Figure 5).

Bomberg's tests yielded few surprises. In general, non-perforated housewraps were found to stop the flow of liquid water and allow the transmission of water vapor. Among his findings: when tested using the LPR test, "Two out of three perforated products failed within a few minutes." This result confirms the findings of Paul Fisette reported in the June 1997 issue of the *Journal of Light Construction*.

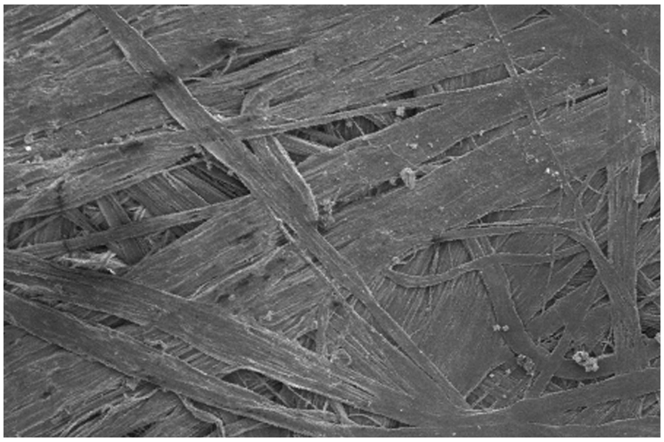
Lab Results Don't Predict Performance

Bomberg is confident that his proposed tests provide numbers that are more useful in evaluating WRBs than existing tests. But scientists still do not know enough about WRB performance to recommend that builders choose a WRB based on test results. As Bomberg wrote, "Whether or not the laboratory results relate to field performance is unknown." When queried on this point, Bomberg elaborated. "The modified inverted cup test doesn't have any relevance to performance, but it does give me a reliable number for comparative tests in the laboratory. The result from this test is higher than one measured on a membrane punctured with nails or staples, and I can use this for computer calculations for the worst-case scenario of field performance," he said. "This kind of vapor transmission really happens for a short period of time when I have a very dry material and a very high influx of moisture. But I don't want to confuse people and say this is realistic."

Even if the building industry agrees that the MIC test accurately indicates vapor permeance, there still remain questions concerning what level of permeance is appropriate for a WRB. As Bomberg himself notes, "In a cold climate, [a] WRB must have a high permeance allowing for an outward diffusion of water vapor, yet not too high permeance, because water vapor flow under reversed thermal gradient, which causes an inward diffusion of water vapor into the wall cavity, should also be limited."

Use Two Layers of Felt or Housewrap

Bomberg advises builders to install flashing properly and to install WRBs in a way that permits drainage. "If



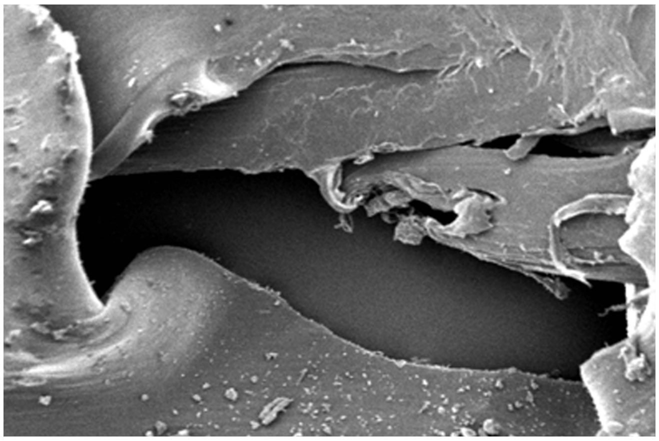


Figure 5. Mark Bomberg proposes classifying weather-resistive barriers according to five categories, including "polymeric fibrous" WRBs (left), a category that includes Tyvek, and "perforated polymeric film" WRBs (right), a category that includes Barricade and Typar. The high magnification of these photos permits a comparison of the materials' pore structures. [Photo credit: DuPont]

a designer designs a structure that prevents collection of moisture behind the WRB by permitting drainage, then you are already eliminating 90 percent of the failure probability," he says. "The other important point is making a proper connection between the WRB and the flashing around windows and other penetrations."

According to Bomberg, drainage is possible in a very narrow gap. "It is not proven that I need more than two or three millimeters of drainage gap," he says. "A lot of building science has run berserk on the ventilated rainscreen principle. A cost/benefit analysis would probably result in the choice of a narrow gap. To be on the safe side, a builder can select two layers of WRB. Two layers and cladding attached with mechanical fasteners provide a degree of drainage which is quite substantial. This is not a liquid water drainage—for free drainage, you need more than four millimeters—but the gravity component helps to move the moisture downwards. You also have a variable thermal gradient that pushes the moisture, sometimes toward the inside and sometimes toward the outside. I call it 'ping-pong thermal drive.' When water comes from small holes or penetrations, you are getting a hydrostatic pressure which pushes water, despite a narrow gap. Gravity plus hydrostatic pressure play a role."

The bottom of a WRB should terminate in a manner that provides access to exterior air. "You need free drainage at the bottom of the wall, a weep hole," says Bomberg. "Most people think of water droplets at the bottom of a wall, but there are no water droplets. I would like there to be good flashing at the bottom and a few openings or holes to get me an air connection."

Most houses would probably benefit from two layers of felt, paper, or non-perforated housewrap. "Two layers of a membrane—whatever the membrane, as long as it is not perforated—are better than one layer of any product, even a highly rated product, because it increases the moisture removal potential—the local drainage plus drying potential," says Bomberg.

A Rose By Any Other Name

In spite of the fact that he has focused a great deal of attention on housewraps, felts, and building papers, Bomberg is not quite sure what to call these products. "We have a big problem with the name," says Bomberg, alluding to Eric Burnett's criticism of the term "weather-resistive barrier" (see ***EDU***, April 2003). "Talking about 'weather-resistive barriers' or 'water-resistive barriers' highlights and exaggerates one aspect of their performance, while these membranes are able to control rain ingress and air and water vapor flow in two directions. I've been talking with Professor Eric Burnett and Theresa Weston [at DuPont] about it. Together we can try to change the name in the next edition of ASTM, but first we have to agree about what name we want to use."

Bomberg doubts the likelihood of widespread adoption of Burnett's suggested term, "the exterior membrane to the exterior sheathing." According to Bomberg, "No one with common sense would use an expression with five or six words when one or two will do. 'Sheathing membrane' is used in the Canadian codes, but the term is awkward in the context of thermal insulation or gypsum boards. I would like to use the term 'exterior membrane.'"

Along with several co-authors, Mark Bomberg has recently written several papers on the topics mentioned in this article. These papers are: *Weather Resistive Barriers: New Methodology for Their Evaluation*; *Weather Resistive Barriers: Laboratory Testing of Moisture Flow*; *Sheathing Membranes (Weather Resistive Barriers—WRB): New Methodology for Evaluation of their Field Performance*; and *Classification of Weather Resistive Barriers*. For more information, contact Mark Bomberg, 2022 Deerhurst Court, Ottawa, ON K1J 8H1, Canada. Tel: (613) 747-7244; E-mail: bomberg@cyberus.ca.

NEW PRODUCTS

Rinnai's On-Demand Water Heater

The Rinnai Continuum is one of the few available on-demand gas water heaters with a high enough flow rate (between 4.5 and 6 gallons per minute) to be used as a whole-house water heater. (The Continuum competes in this category with the Aquastar 240FX, an on-demand water heater with similar specifications.) According to Rinnai, the Continuum can satisfy two or three simultaneous showers (see Table 2). Where local codes permit, the Rinnai Continuum can also be used for space heating.

The Continuum has sophisticated controls that monitor the temperature of the input water. These controls adjust the unit's flow control valve and its modulating burner (which can deliver from 15,000 to 180,000

BTU/h). "The outlet temperature has priority," says Dan Driscoll, manager for Rinnai for Northeast region for water products. "At five gallons per minute, the Continuum can provide a 70-degree temperature rise. But what happens if you ask for eight gallons per minute to fill a whirlpool tub? Without the right controls, the outlet temperature would drop. The Continuum senses the flow and adjusts the flow control valve as necessary to hold the outlet temperature, because the outlet temperature is more important than the volume. It will deliver water at the outlet within 1 or 2 degrees of the temperature setting."

The Continuum 2532 replaces model 2424, which Rinnai no longer manufactures. The 2532 is available in two residential models and two commercial models. The residential versions are the 2532FFU (an indoor direct-vent model with fan-assisted combustion) and the 2532W (designed for exterior mounting). The two commercial versions are the 2532FFUC (for indoor mounting) and the 2532WC (for outdoor mounting).

Hydronic Heat

If the Continuum will be used for space heating, Rinnai recommends choosing the commercial model, which costs about 15% to 20% more than the residential

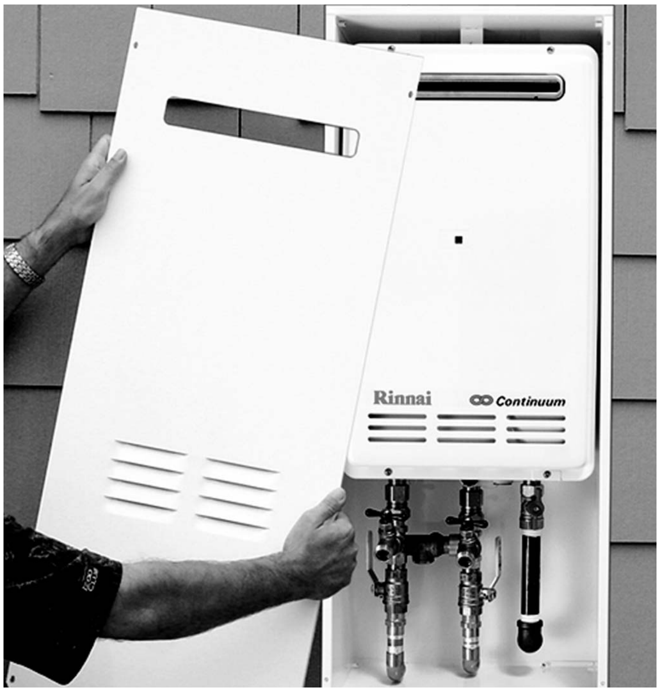


Figure 6. Rinnai produces several models of its Continuum on-demand gas water heater, including models designed for outdoor installation. The outdoor models use an electric resistance heater and intermittent firing of the gas burner to protect the unit from freeze damage, even in -30°F weather.

Table 2—Rinnai Continuum Specifications

	Indoor unit (model 2532FFU)	Outdoor unit (model 2532W)
BTU/h input	15,000 - 180,000	15,000 -199,000
Gas line diameter	3⁄4 inch	3⁄4 inch
Energy Factor	82% for natural gas, 87% for propane	84% for natural gas, 85% for propane
Maximum flow rate at 70°F temperature rise	4.8 gpm	4.8 gpm
Standby electrical power use	5 watts	5 watts
Electrical power use when operating	75 watts	72 watts
Electrical power use during frost-protection cycle	100 watts	84 watts
Retail price	$1,140	$1,110

Table 2. The two available residential models of the Continuum 2532 have slightly different specifications.

model. “When used as a heating appliance, you have more firing cycles in one day, so you are putting more stress on the unit,” says Driscoll. “The heat exchanger for the residential unit is type K copper, but on the commercial unit the heat exchanger has an added cupro-nickel alloy so that it can handle more expansion and contraction.”

All four models include freeze-protection features. In cold weather, an 84-watt electrical resistance heater keeps the Continuum above 42°F. When the outdoor temperature drops to about -10°F, freezing is prevented by automatic intermittent operation of the gas burner. “The unit holds about three-quarters of a gallon of water,” says Driscoll. “An aquastat looks to keep the water temperature above 42 degrees. If necessary, the burner will kick in every five minutes for a few seconds.” In the event of a power failure, solenoid valves open up and drain the water from the unit. Rinnai claims that the Continuum is protected against freezing down to -30°F. But in a cold climate, operation of the outdoor model’s electric resistance element costs about $40 per year in electricity, so energy-conscious builders in the North should choose the indoor model (see Figure 6).

Potential Savings

Since the Continuum has an Energy Factor of 82% or 84% (depending on the model), users will save energy compared to tank-type water heaters. Rinnai’s figures show that the Continuum consumes 21% less gas than the best available tank-type heater, or 48% less gas than the worst available tank-type heater. Using Rinnai’s estimates, a typical household paying $0.84/therm for natural gas will save between $40 and $139 per year by switching from a tank-type heater to a Continuum for domestic hot water. According to a head-to-head test conducted by the Okaloosa Gas District in Valparaiso, Florida (posted on the Web at *www.okaloosagas.com/waterheatertest.cfm*), a Rinnai Continuum saved $6.91 per month ($83 per year) when compared to a 40-gallon gas-fired Rheem water heater.

Who’s Buying Them?

The payback period for the $870 incremental cost of a Continuum (compared to a tank-type heater) will vary from about 6 to 12 years, depending on fuel costs and hot water usage. “You don’t buy a Rinnai because you will save money on your monthly utility bills,” notes Gary Long, marketing head at Okaloosa Gas District. “The savings are there, but that’s not why you buy it.” According to Long, builders like the wall-mounted Continuum because it saves valuable floor space.

Ironically, the Rinnai Continuum is not necessarily being purchased by energy-conscious homeowners. “The niche for this product is a homeowner who doesn’t want to run out of water,” says Driscoll. “Every year people are using more and more domestic hot water, and we see the Continuum going into bigger custom homes. In some cases we’ll pair two of these together for a large-flow system of up to twelve gallons per minute. We installed two of the units recently in a new house with a $5,000 body-spray system in the master bathroom.”

For more information, contact Rinnai America,
103 International Drive, Peachtree City, GA 30269.
Tel: (678) 829-1700 or (800) 621-9419;
Fax: (678) 829-1666; E-mail: sales@rinnai.us;
Web site: *www.rinnai.us*.

INFORMATION RESOURCES

Solar Energy Houses

Solar Energy Houses is a technically detailed and well illustrated book that provides a wealth of ideas for designers of energy-efficient houses. The book reports on the results of the Task 13 project sponsored by Solar Heating and Cooling Program of the International Energy Association (IEA).

The Task 13 participants set out to design, build, and monitor the performance of fourteen energy-efficient prototype houses incorporating passive solar features. Participating in Task 13 were technical teams from twelve countries: Belgium, Canada, Denmark, Finland, Germany, Italy, Japan, the Netherlands, Norway, Sweden, Switzerland, and the US.

An Ambitious Goal

The goal of the Task 13 participants was to design houses using 75% less energy than “typical” new houses in the same climate. The goal was not quite achieved; on average, the houses used 60% less energy than typical houses. Although each of the houses had some budget limitations, designers incorporated energy-efficiency measures without regard to their cost effectiveness.

The designers’ first priority was to minimize required energy inputs by designing tight, well-insulated shells. The second priority was to maximize the benefits obtained from passive solar features. The third step was to evaluate and incorporate active solar features where appropriate.

The design teams came up with a variety of solutions to the challenge before them. One of the US houses, the Grand Canyon house, included an unvented Trombe wall. The other US house, the Yosemite house, had walls built of expanded polystyrene sandwiched between two layers of shotcrete. One of the two Canadian houses, the Brampton house, was built with double 2x4 walls filled with blown-in cellulose.

Common Features

In spite of the fact that the houses were designed for different climates, from Japan to Arizona to Norway, the Task 13 houses have much in common. All of the houses included a high level of attention to airtightness, above-average levels of insulation, high-performance windows, and heat-recovery ventilation systems.

All of the designers intended their houses to have tight shells. One of the Canadian houses, the Waterloo house, measured 0.8 air changes per hour (ac/h) at 50 Pascals, well below the R2000 standard of 1.5 ac/h. But reducing air leakage proved more difficult for Belgian than Canadian builders. At the Belgian Task 13 house, the first blower-door test showed 5 ac/h at 50 Pascals; after air-sealing improvements were made, the house was re-tested and measured 2.05 ac/h at 50 Pascals.

The authors of *Solar Energy Houses* provide the following rule of thumb: "Use at least twice the amount of insulation prescribed in building codes or used in standard practice." On average, the Task 13 houses had R-31 walls and R-43 roofs.

Triple- and Quadruple-Glazing

For most of the Task 13 houses, especially the high-latitude houses, a window's U-factor proved more important than its solar heat gain coefficient (SHGC). Unconstrained by considerations of cost-effectiveness, the Task 13 designers chose windows with unusually low U-factors—on average, U-0.218 (R-4.6). Among the houses with triple-glazed windows were the two Canadian houses and the two German houses. The Norwegian house elected to use windows with quadruple glazing, while the Finnish house used quintuple-glazed windows with a U-factor of 0.123 (R-8.13). Almost all windows were argon- or krypton-filled and incorporated one or two surfaces with a low-e coating.

Virtually all of the Task 13 houses included heat-recovery ventilators (HRVs). In the Dutch house, two HRVs were installed in series to maximize heat recovery. Several houses used sunspaces to preheat ventilation supply air. The designers of the house in Rottweil, Germany took a different approach: that house's ventilation supply duct is a 111-foot-long 8-inch diameter plastic pipe, buried three feet below grade to allow the warm earth to preheat ventilation air.

What the Sun Provides

In general, superinsulation trumps solar. Although passive solar gains contributed useful heat to all of the Task 13 houses, the sun is notably absent in many northern climates when it is most needed: "Solar gains are minimal in mid-winter, from December through mid-February, but make a major contribution in the fall and spring seasons, when heating requirements are still substantial." In some areas, including much of Arizona, passive solar features can greatly reduce the need for supplementary winter heat. But in high-latitude locations like Norway, no matter how sophisticated the glazing, even south-facing windows are net energy losers over the heating season. In such climates the "ideal" house has no windows at all, and passive solar principles are useful only in spring and autumn.

A few of the houses included active solar heating systems. For example, the Finnish house included roof-mounted solar thermal panels and an 800-gallon hot water tank (see Figure 7). In Denmark, however, the designers concluded, "In a super-insulated house, it is difficult to justify the capital cost of a space-heating solar system. Although a large part of the heating load can be covered, the absolute savings are small."

The most ambitious active solar heating system was installed in the Berlin house, which was designed as a "zero heating energy" house. That goal, however, was not met, and the house required supplemental heat. The culprit was unexpected air leakage; the house's shell never achieved the level of airtightness assumed by the designers. Summing up the lessons learned from all of the Task 13 houses, the authors conclude, "Active solar space heating is technically feasible but not cost-effective."

Performance Monitoring

In several houses, including the Brampton house in Canada and the Finnish house, designers significantly underestimated the "parasitic" power requirements of pumps and fans. Although the Task 13 houses used more energy than predicted, they were still remarkably efficient, requiring an average of 60% less energy than comparable "typical" houses. One of the star performers was the Norwegian house: "The total auxiliary energy need is 33 kWh/m^2. This is about 15% of the amount needed in similar dwellings built according to the existing building code."

Since the Task 13 houses had well-insulated shells, they used, on average, more energy for domestic hot water (23 kWh/m^2) than for space heat (20 kWh/m^2).

Lessons Learned

As might be expected, some of the buildings had problems. Two houses (the ones in Denmark and Norway) sometimes overheated during sunny weather, and in two others (one in Germany, one in the Netherlands), occupants complained that the ventilation systems were noisy. Yet most of the buildings were quite successful. Among the general conclusions made by the Task 13 teams:

- "Solar DHW is an effective way to reduce water heating requirements."
- "The largest reduction in energy consumption for space heating in the Task 13 buildings is achieved by the use of traditional energy conservation technologies"—that is, high-performance windows, high levels of insulation, and tight construction.
- "High levels of insulation are beneficial in all climates, including those where cooling is the major issue. Super-windows, i.e. windows with multiple layers, low-e coatings, and gas fillings, are also always beneficial."
- "The simpler the system, the less that can go wrong. … High-performance envelope components are safer investments than technical energy systems."

Although the authors of *Solar Energy Houses* note that neither active solar space heating nor photovoltaic arrays are cost-effective, the book would have benefited from greater attention to the cost-effectiveness of other components, especially windows. Neither builders nor homeowners are likely to invest in features burdened with incremental costs greater than foreseeable energy savings. That said, the Task 13 houses are inspiring examples of energy-efficient residential construction, with many useful lessons for designers and builders.

Figure 7. The roof of the Task 13 house built in Pietarsaari, Finland, supports 27 square feet of solar thermal collectors and 2 kW of photovoltaic modules.

Solar Energy Houses (ISBN number 1-902916-43-3) is available for $70.00 from James & James Science Publishers, 8-12 Camden High Street, London NW1 0JH, United Kingdom. Tel: 44 20 7387 8558; Fax: 44 20 7387 8998; E-mail: jxj@jxj.com; Web site: *www.jxj.com*.

READERS' FORUM

Closing Crawlspace Vents Limits Stack Effect

Dear Editor,
I'm a little slow at responding to the article titled "Experts Discuss Crawlspace and Basements" (***EDU***, May 2003), but I felt it is important to add some real-time facts to the discussion.

My experience in these matters include 18 years running electric utility conservation programs, auditing hundreds of buildings, before and after weatherization. I am a licensed contractor and own 18 single-family rental houses where I do all the maintenance.

In addition to the above experience, I lived in a house for more than fifteen years that had standing water under it all year. The water table was 9 inches under the surface and some of the surface in the crawlspace was below the water table. There were no vents in the crawlspace or attic. We had lots of mildew in the bedrooms and bathroom only, but not in the crawlspace, until we installed a 6-mil ground cover and insulated the perimeter with R-19 metal building insulation, down the block stem-wall then out 3 feet on top of the plastic. Years later there was dust on the plastic and water and mud underneath. We never had a mold or mildew problem again.

Vapor pressure does not act the same way as air infiltration, especially in a crawlspace with a ground cover, because there isn't any free air flow under the plastic. Moisture and stack effect through a hole in the ground cover are relative to the size of the hole, not the size of the crawlspace. We have verified that moisture problems disappear when a ground cover is installed and the stack effect is nearly eliminated.

We have an ongoing study of crawlspaces. We are checking the moisture of the wood at various locations in the crawlspace. This data will be supplemented by a study that is going to be conducted on new tract homes with the same floor plans. This study, funded in part by DOE, will examine stack effect and moisture in vented and non-vented buildings. Results are expected some time next year.

Our own moisture testing shows that plumbing leaks are a minor problem, especially when a ground cover is present. Our moisture tests show that puddles have little or no effect on the wood above them. I've looked at hundreds of houses with leaks and water on the plastic, and any mold problems from leaks were isolated to the wetted area and did not affect the whole crawlspace. (As a precaution, when we find leaks we make a small slit in the plastic that allows the water to go under the plastic, and then we notify the homeowner of the problem.)

Many studies have been conducted by ASHRAE and others, and the unanimous conclusion is that non-vented crawl spaces are drier than vented ones, even in areas with high humidity. Since we are not likely to stop building with crawlspaces, why not just do it right—install perimeter insulation and no open vents? Vents cannot dry the crawlspace unless the actual moisture content outside is lower than the crawlspace. In our northwest irrigated desert climate, the summer air is much wetter than the crawlspace. In the winter our air is very dry but venting would increase the heating cost.

By evaluating customers' bills, we've learned that homes with perimeter insulation use less energy than those with floor insulation and open vents, as is required by the current state energy code. The factors that make this happen are high ground temperature (56° to 61°F) and perimeter insulation.

Our conclusions:

1. Venting usually increases moisture problems and is the most likely cause of nearly all non-leak related mold and mildew inside the home and attic, caused by the stack effect.
2. Eliminate the stack effect and eliminate moisture problems.
3. Venting by itself does not solve moisture problems.
4. ASHRAE is right: non-vented crawlspaces are drier than vented ones and a plastic ground cover does, in most cases, solve moisture problems.

[Edited for length]

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