IN DEPTH

Advances in Understanding Durability of the Building Envelope: ORNL Research

Moisture, and its accompanying outriders – things like mold, corrosion, freeze damage, and decay – present powerful threats to the durability and long-term performance of a building envelope. Miscalculating the impact of environmental factors like rain, solar radiation, temperature, humidity, and indoor sources of moisture can cause significant damage to many types of building envelope components and materials, and also can lead to unhealthy indoor living environments.

As described by Joseph Lstiburek, B.A.Sc., M.Eng., Ph.D., P.Eng., principal of Building Science Corporation, moisture accumulates in the building envelope when the rate of moisture entry into an assembly exceeds the rate of moisture removal. When moisture accumulation exceeds the ability of the assembly materials to store the moisture without significantly degrading performance or long-term service life, moisture problems result. But what happens when solar-reflective exterior surfaces, and airtight and high-R envelope assemblies are thrown into the mix? This question becomes more significant when anticipating expanded retrofit activity to improve existing building envelopes.

To better understand energy efficiency features and their interaction with moisture and ultimately durability, Oak Ridge National Laboratory (ORNL) has established a new experimental facility and initiated several studies, including an examination of the relationship between air tightness and moisture durability, hygrothermal performance of below grade construction as a function of soil type, and moisture levels associated with cool roofs.

These current studies are grounded in a history of building envelope moisture durability research at ORNL, sponsored by the US Department of Energy (DOE) Building Technologies Office and industry partners. “We became involved in moisture, and its effects on efficiency, shortly after a rash of lawsuits were filed in the late 1990’s. These suits centered on moisture-related failures of energy efficient building envelopes,” explained Andre Desjarlais, Group Leader, Building Envelope Research Group at ORNL. “A general concern arose that as building envelopes became more airtight and energy efficient, they were also losing their drying potential, with moisture-related failures being the unintended consequence. There was push back against energy efficiency improvements because of concerns about durability.”

Could energy efficiency and durability be achieved at the same time? In 1998, ORNL began its partnership with the Fraunhofer Institute for Building Physics (IBP) to develop
While its accuracy has been validated over a number of years, both by the Fraunhofer IBP and ORNL, against data from numerous full-scale field studies of building envelope assembly performance, ORNL’s latest projects will once again test WUFI’s mettle.

**Air Tightness and Moisture**

“Effects from the Reduction of Air Leakage on Energy Use and Material Durability,” a study led by Diana E. Hun, Ph.D., P.E., Building Technologies Research and Integration Center, ORNL, and currently in peer review, examined the impact of increased airtightness, indoor moisture sources, the moisture capacity of materials in the wall cavity, the thermal resistance of continuous exterior insulation, and the amount of winter solar radiation on 28 walls installed at the Building Envelope Systems Testing (BEST) laboratory in Syracuse, New York, Department of Energy (DOE) Climate Zone 5. Assessed walls had insulation with a thermal resistance of 3.7 K·m²/W (RUS = 21 h·ft²·°F/Btu), classifying them as High-R walls (~3.2 < RIS < ~7 K·m²/W, ~18 < RUS < ~40 h·ft²·°F/Btu). Additionally, wall panels in this study had approximate air leakage rates of ≤ 0.02 L/(s·m²) (Level 1), ≤ 0.2 L/(s·m²) at (Level 2), or ~ 1 L/(s·m²) (Level 3) at a pressure differential of 75 Pa. These leakage levels were selected from air barrier compliance options set by the 2012 International Energy Conservation Code (IECC) for commercial buildings.

Hun and her team monitored the installed walls over 12 months, from October 2011 to November 2012, logging temperature, relative humidity, humidity ratio, and water vapor pressures at the inner surface of the exterior sheathing; as well as heat flow through the interior drywall. Additionally, outdoor conditions were gathered from an onsite weather station (see Figure 1).

“The main question we wanted to address here is, if you improve air tightness, are you compromising moisture durability of the envelope?” said Desjarlais.

WUFI, today in its fifth major release version, is one of the most advanced commercially available hygrothermal simulation programs in use, with computations taking into account factors such as water absorption, liquid and vapor moisture transport, and night sky radiation.
Notable among initial findings was the impact of air leakage on energy loads. These effects were evaluated by using heat fluxes through the Level 1 walls as the baselines; their low air leakage implied that fluxes through them were primarily due to conduction. Maximum temperature differences between the Level 3 and Level 1 walls occurred during December and January, and these months also saw Level 3 wall panel heat fluxes that were up to 54% higher than those for Level 1. Differences between Level 2 and Level 1 walls maxed out at 11%.

“The magnitude of increase in energy loss due to air infiltration was a surprise,” said Desjarlais. “The level of air leakage we were evaluating was below that set by IECC levels, and the walls were fairly efficient, with an approximate RUS-21 insulation rating. The large increase in heat flow between Level 3 and Level 1, and resultant energy implications, was somewhat startling.”

In relation to air tightness and moisture, humidity ratios at the inner surface of the exterior sheathing were tracked, given that this is typically a critical location for moisture problems. These ratios increased from winter to summer, and decreased from summer to fall. Level 1 panels, representing the tighter walls, typically had higher monthly average humidity ratio measurements during the winter. This was due primarily to the fact that tightly-built walls rely on diffusion, rather than airflow, to remove excess moisture. This limitation was exacerbated by wall orientation. “If walls are facing north, east, or west during winter they receive less solar radiation, and experience weaker solar-driven diffusion to dry toward the indoor space,” said Hun. “The same panels facing south had lower humidity ratios in the cavity.”

Nevertheless, as outdoor water vapor increased from winter to summer, infiltration raised humidity ratios in the leakier panels (those classified as Level 2 and 3) at a faster rate than in the tighter walls (Level 1), so that humidity ratio values in the Level 3 exterior sheathing became similar to the ratios in the Level 1 walls.

“We also found that, in terms of likelihood of mold growth, in addition to certain variables like relative humidity indoors and air tightness, the moisture capacity of materials played a part,” Hun commented. “There was a large difference between results from walls with wood exterior sheathing, and those with XPS rigid foam or glass mat gypsum sheathing. Walls framed with wood tended to have lower relative humidity values in the cavity as the wood materials served as a buffer.”

By analyzing sorption isotherms, the capacity of wood to store water vapor helped maintain humidity ratios in wood framed walls at a lower level than in wall panels constructed using materials with a lower moisture storage capacity. The results imply that buildings located in cold climates and having envelope materials with low moisture capacity, which are more typically found in commercial construction, can be susceptible to moisture problems.

Other observations hit home in residential envelopes. “When we use rigid foam insulation as exterior sheathing, people have been leaning towards not putting oriented strand board (OSB) across the envelope, other than to reinforce the exterior foam at the corners from wind shear. This is the first data that suggests that if OSB is left out, you leave behind its moisture storage capacity, and you are potentially reducing the durability of your wall system,” Desjarlais stated. “In the walls that Hun evaluated, it is also apparent that when you move all of your insulation outboard, placing all of the R-value outside of the cavity of the wall, moisture performance increased. The higher the R-value of insulation applied outside of the wall cavity the warmer the temperatures in the cavity, which helps maintain a lower relative humidity.”

“With increased requirements on air tightness, there will be a change in moisture behavior in the envelope assembly,” summarized Manfred Kehrer, Building Envelopes Research, Building Technologies Research and Integration Center, ORNL. “The best envelope is totally airtight – no air often means less moisture, but this cannot be achieved in practice. To reduce energy leaks we increase air tightness but therefore we also reduce air speed through the wall, which means there is time for condensation to occur. So unless we are careful with the details of the envelope assembly, with increased air tightness, what were energy leaks have the potential to become moisture leaks.”

“What this field work shows is that you can achieve energy efficient, durable walls if you are more careful about material choice and wall assembly configuration,” Hun said.

Desjarlais agreed. “This is the reason for developing models and tools. If you double the R-value of a wall, suddenly, moisture isn’t so black and white. To borrow Kehrer’s analogy, you’re walking along the cliff, and if you take that one extra step, you’re in trouble. So many things are happening at once in a highly energy efficient wall. You’ve got water vapor, rain possibly penetrating the cladding, sunshine, the relative humidity...
outside, the relative humidity inside—it’s more complicated than many people have been led to believe. In fact, it’s hard, if not impossible, to develop an intuitive sense of the best wall across all situations, because of the complexity of all of these factors. The industry needs to have a tool that can accurately forecast interactions and determine whether a given envelope assembly is durable in a given climate or not.”

“It is not one specific material or thing you have in a wall,” stressed Kehrer. “Rather, successful, energy efficient walls that will last are always about the right design of the overall assembly, depending on the climate zone, and on how people live in that building. It is always about all of the layers working together.”

“We’re greedy. We want superior energy efficiency and we want walls that will last,” said Patrick Hughes, Director of the Building Technologies Research and Integration Center, ORNL. “In most climates and applications there are multiple ways of improving buildings for energy efficiency while also retaining moisture durability. But the most cost-effective way in reality may not be the one you would pick first, and if you haven’t considered moisture your pick is at risk of a moisture-related failure. For new construction, use of accurate simulation tools enables forgiving, moisture-durable, and cost-effective envelope assemblies to be prescribed in energy codes. For retrofits, the tools can be used to verify that what you’re contemplating doing, will be moisture-durable, before you do it.”

This most recent field study, led by Hun, adds to a pedigree of field verification efforts that will eventually lead to enhancements of WUFI.

“Back in 2007, ORNL began using US data to validate WUFI, in partnership with the Exterior Insulation and Finish Systems (EIFS) Industry Members Association (EIMA)®,” Desjarlais explained. “The effort began in the very challenging hot and humid DOE Climate Zone 3 with the construction of a natural exposure test facility in Charleston, South Carolina where dozens of wall assemblies could be evaluated side-by-side. After the lawsuits in the late 1990s, EIMA was anxious to prove a family of exterior insulation and finish systems could effectively manage moisture and achieve energy efficiency without compromising durability. From there, we did a large number of building envelope simulations to expand this field-based hypothesis into other climates. Our research found that appropriately designed EIFS assemblies are working in every climate zone.”

“Compared with other tools, WUFI has been more successful with matching simulations to experimental field results,” added Kehrer. “Of course WUFI is not perfect either, but we know where the WUFI model works well, and where we have to improve our characterization of the behind-the-scenes complex physics.”

**Below Grade Construction and Soil Moisture**

In an effort to further increase WUFI’s scope, and thus enhance the simulation tool’s usefulness to the buildings industry, ORNL is expanding WUFI capability to handle below grade construction by adapting soil properties information into the database. While approaches exist to calculate heat transfer and some capillary action, ORNL’s team hopes to expand the below grade hygrothermal picture by determining the influences of soil moisture storage, liquid water transfer, vapor diffusion resistance, dry bulk and particle density, porosity, thermal conductivity, and specific heat capacity. The research should bring greater clarity to parameters such as liquid uptake of precipitation and liquid flow.
ORNL’s work will also gauge the reliability of the soil parameters, by comparing simulation predictions against ongoing in-field measurements for temperature and soil moisture content, together with measured boundary conditions (see Figure 2).

“The final outcome of the study will be the evaluation of several soil types in several climate zones for a number of basement assembly types,” stated Kehrer. “The study will define the type of soil, together with the type of building construction considered most and least reliable with respect to energy consumption and moisture durability.”

Currently, WUFI simulation software does not allow for full absorption of precipitation at the ground surface if the outer element is already saturated with moisture, and better models are needed to more accurately simulate the moisture transfer mechanisms. Additionally, WUFI cannot simulate the impact of snow cover on heat transfer at the ground surfaces. ORNL research will try to fill in these gaps.

“These are examples of how we’re leveraging field evaluations and research to enhance WUFI, so that we are able to make more generalized conclusions and best practice recommendations,” stated Roderick K. Jackson, Ph.D., Whole-Building and Community Integration, Building Technologies Research and Integration Center, ORNL. “I think this type of coupled approach versus just taking a research approach with tools or experiments alone, will continue to be the direction going forward.”

Moisture in Cool Roofs
Besides verification investigations into moisture implications of air tight walls and below grade construction, ORNL also unveiled results evaluating possible increased condensation risk in cool roofs. According to a study by Ennis & Kehrer, 2011, cool roofs with a mechanically attached membrane (see Figure 3) have shown a higher risk of intermediate condensation in the materials below the membrane in certain climates and in comparison with similar constructions with a darker exterior surface. This risk is affected by climatic loads, indoor moisture sources, and air intrusion rates.

“There have been lots of articles in the last 1 or 2 years that just mention there is a problem with cool roofs in some applications, but offered no answers,” explained Kehrer. “Our study is the first one that addresses what works and what doesn’t, and why. We looked at the influence of climate zone, air tightness of the roof, and interior conditions. The results really make sense.”

The results, compiled in Kehrer’s “Condensation Risk of Mechanically Attached Roof Systems in Cold Climate Zones,” emphasize the importance of solar reflectance at the roof surface. In cool roofs, the maximum condensate layer thickness is almost double that of a traditional black roof. In a cool climate, cool roofs run a much greater risk of condensation. Additionally, Kehrer’s work shows that a low or a high indoor moisture supply can cause a difference up to 10 times as great in condensation. If indoor moisture is kept at low levels, or air intrusions are kept low (a safe upper limit of air leakage at 50 Pa, Q50, is stated as 0.17 l/s,m2 for metal roofs (Hens et al., 2003)), there is little risk of intermediate condensation in a roof.

“There have been lots of articles in the last 1 or 2 years that just mention there is a problem with cool roofs in some applications, but offered no answers,” explained Kehrer. “Our study is the first one that addresses what works and what doesn’t, and why. We looked at the influence of climate zone, air tightness of the roof, and interior conditions. The results really make sense.”

“Nothing really surprised us from the results,” said Kehrer. “Some of the wind flow assumptions could be weak, but no better data exists, so they are reasonable as best we can tell.”

“What we were seeing across the industry was effectively a condemnation of cool roofs,” added Desjarlais. “This, of course, is nonsense. Our message is simply that you do need to consider moisture when designing envelope assemblies, including cool roof assemblies. This study shows that you can have problems with traditional black roofs too, if indoor moisture levels are high, or there are high rates of air intrusion. Believe it or not, there had really never been a moisture durability study of mechanically attached roof systems even though they are the most widely used in this sector. Now that the tools are available industry seems eager to use them to reduce their risk.”
Taking Snapshots of ORNL’s Work

What are the most valuable lessons a builder can walk away with from this recent slate of ORNL work?

“When you have any kind of envelope, don’t make it vapor tight on both the indoor and outdoor sides, make the envelope a little forgiving in case of bad workmanship,” noted Kehrer. “If at all possible, allow a wall to dry in both directions, but at least one.”

“And by drying, this means by diffusion, not by air flow, otherwise you have a non-efficient envelope,” clarified Hughes.

“One time-honored, demonstrable way to protect the building envelope from moisture damage is to properly protect construction material from weather on the jobsite,” Desjarlais stated. “A major cause of failure is initial high levels of moisture in building materials. A builder will have substantially more issues if he doesn’t take care of building materials as they are shipped and stored on site. Reduce the amount of water in the structure when you first construct it.”

“My advice to homeowners is to control your sources of moisture indoors,” said Hun. “In general, this means properly ventilate bathrooms and the cooking area, which are among the major sources of moisture in a home. My advice to builders is to provide adequate mechanical ventilation in residences with tightly-built envelopes because this will help control indoor moisture levels in the winter and maintain acceptable indoor air quality throughout the year.”

“Certainly as people build or remodel, it is worthwhile to do a quick analysis. You would much rather find a problem in the computer than in your building,” commented Desjarlais. “This very goal, achieving energy efficiency without sacrificing moisture durability, is the intent behind ASHRAE 160 and WUFI. Our basic WUFI simulation makes these calculations easy and affordable in time and dollars to conduct a moisture durability analysis. You can’t expect a professional to spend a week to do analyses; the industry needs a straightforward tool that is easy to use and gets results in a reasonable period of time.”

“Call me practical or maybe just old, but after observing the fate of building energy simulation over the last 40 years, with the exception of a few production builders, I am somewhat skeptical that residential builders and remodelers will be embracing building moisture simulation on a project-by-project basis,” commented Hughes. “For new construction I see no reason why energy efficient, moisture-durable, and forgiving building envelopes cannot be prescribed in energy codes. However with retrofits, what is safe to do as an energy improvement depends on climate and the details of your existing envelope assembly. I think the materials supply chains need to step up with better technical market support tools to make the durability consideration as easy as possible for remodelers.”

Upcoming Work

Expanding its arsenal of experimental capabilities, the air and moisture penetration chamber is among the newest facilities at ORNL (refer to Figure 4). This apparatus will enable researchers to study the effects from air and moisture penetration through walls while sustaining selected temperature and humidity gradients across large-scale wall specimens, and simultaneously simulating positive and negative wind/gust pressures across the wall, as well as rain and/or solar radiation on the outdoor surface of the wall. The chamber also allows for accelerated tests that assess the long-term performance of new and retrofitted wall assemblies, enabling researchers to document cyclical effects of weather on airtightness and moisture content.

“We are beginning a project with Building America that will further evaluate the durability of energy efficient walls for new and existing residential construction in the new chamber,” Hun said. “While it will be somewhat similar to our Syracuse field test, evaluations are accelerated in the sense that we can control indoor and outdoor cycles without waiting for weather to happen. We can use the chamber to replicate the most challenging sequences of weather and monitor whether thresholds for moisture-related failures are being reached in these walls.”

“Materials suppliers and large regional and national contracting organizations are also beginning to engage with ORNL to develop technical market support tools leveraging our envelope energy efficiency and moisture durability expertise,” said Hughes. “The goal of these tools is to make the durability consideration as easy as possible.
for those interested in increasing the energy efficiency of residential and light commercial building envelopes.”

Energy Design Update thanks Oak Ridge National Laboratory for sitting down with us and sharing their latest research. To visit ORNL Building Technologies online, go to http://www.ornl.gov/science-discovery/clean-energy/research-areas/buildings.

André Desjarlais is the Group Leader for the Building Envelope Research Program at the Oak Ridge National Laboratory. He has been involved in building envelope and materials research for over 40 years, first as a consultant and, for the last 23 years, at ORNL. Areas of expertise include building envelope and material energy efficiency, moisture control, and durability. Desjarlais has been a Member of the American Society for Testing and Materials (ASTM) since 1987 and serves on Committees C16 on Thermal Insulation, E06 on Building Systems, and D08 on Roofing. He is the past Chairman of ASTM Committee C16. Desjarlais has been a member of ASHRAE since 1991 and serves on Technical Committees TC 4.4 on Thermal Insulation and Building Systems, TC 1.8 on Mechanical Insulation Systems, and TC 1.12 on Moisture Control in Buildings, and is past Chairman of TC 4.4.

Patrick Hughes, P.E., serves as Director of ORNL’s Building Technologies Research & Integration Center (BTRIC, http://www.ornl.gov/sci/ees/etsd/btric/). The BTRIC areas of focus are advanced building technologies, whole-building and community integration, and improved energy management in buildings and industrial facilities during their operational phase. BTRIC has a full-time staff of approximately 80 researchers and includes a Department of Energy (DOE)-designated National User Facility that supports ORNL research sponsored by DOE and others, in collaboration with industry, universities, associations, and utilities. Hughes served as an ORNL Group Leader (2001-04) and Senior Research Staff member (1989-2001) prior to his current position. Awards received by Hughes related to building energy efficiency include a DOE Energy Innovation Award in 1987; the International Ground Source Heat Pump Association’s “Outstanding Engineering Achievement Award” in 1998; and ORNL Significant Event Awards in 1993, 2010 and 2013.

Diana E. Hun, Ph.D., P.E., is an engineer for the Building Envelope Research group at ORNL. She is currently evaluating the performance of air barrier technologies and studying the optimisation of building energy demands and indoor air quality. To this end, she is collaborating with the Air Barrier Association of America (BAAA) and its participating research members, Building America, the US-China Clean Energy Research Center Building Energy Efficiency (CERB BEE) consortium, and various universities. Hun received her Ph.D. from the University of Texas at Austin, where she studied human exposure to hazardous air pollutants in homes.

Roderick Jackson, Ph.D., R&D Staff, Oak Ridge National Laboratory, joined ORNL in 2009, and is currently on the R&D Staff of the Whole-Building and Community Integration group and is responsible for providing sub-programmatic management for residential building integration and deployment (RBID) research. Jackson’s research is primarily focused on the integration of technologies and best practices that maximize cost-effective energy efficiency in residential buildings. He leverages over six years of residential construction experience with four years served as president of a general contracting firm, where he managed custom-built new construction and retrofit residential projects. At ORNL, he also conducts energy policy research and analysis to facilitate comprehensive technical, social, and economic solutions to the energy and climate challenges currently facing the US. Dr. Jackson received his B.A., M.S., and Ph.D. in mechanical engineering from the Georgia Institute of Technology.

Manfred Kehrer is a senior staff member in the Building Technologies Research and Integration Center at Oak Ridge National Laboratory. Kehrer worked at Fraunhofer IBP Germany, for 10 years in the laboratory of the Hygrothermics Department. He then moved to the software development group where he worked on modeling, programming, and testing of the transient hygrothermal transport calculation (WUFI), and eventually became the group manager. Since 2011, he has worked as a senior researcher within the Building Envelopes Group at Oak Ridge National Laboratory, where he is in charge of hygrothermal investigations.

IN BRIEF

First Annual Housing Innovation Award Winners Announced

On October 4, 2013, the US Department of Energy (DOE) presented the inaugural winners of the first-ever Housing Innovation Awards. The Awards recognize 46 diverse industry leaders bringing the best in energy efficient building technologies and design to new and older homes and helping households save money. The competition, coordinated by the DOE Office of Energy Efficiency and Renewable Energy,
offered rigorous application criteria within four building categories: DOE Challenge Home Builders, Home Performance with ENERGY STAR® Participating Contractors, Excellence in Building Science Educator of the Year, and Building America Top Innovations. The Housing Innovation Awards recognize leading builders, contractors, researchers, national laboratories, and building science organizations who are helping communities across the country save money and energy and are leading the way to affordable, comfortable, zero net-energy ready homes.

The DOE Challenge Home Builder Awards are presented to builders who are changing the way homes are designed and constructed.

**System Builders**
- Weiss Building & Development, LLC, South Elgin, Illinois [Grand Winner] (Figure 5)
- Clifton View Homes, Whidbey Island, Washington [Winner]
- Dwell Development, Seattle, Washington [Winner]

**Custom Builders**
- Preferred Builders, Inc., Greenwich, Connecticut [Grand Winner] (Figure 6)
- BPC Green Builders, Wilton, Connecticut [Winner]
- Caldwell & Johnson Custom Builders & Remodelers, North Kingstown, Rhode Island [Winner]
- e2 Homes, Winter Park, Florida [Winner]
- StreetScape Development, LLC, Libertyville, Illinois [Winner]
- Transformations, Inc., Townsend, Massachusetts [Winner]
- Weiss Building & Development, LLC, South Elgin, Illinois [Winner]

**Production Builders**
- New Town Builders, Denver, Colorado [Grand Winner] (Figure 7)
- Garbett Homes, Salt Lake City, Utah [Winner]
- KB Home, Los Angeles, California [Winner]
- Nexus Energy Homes, Stevensville, Maryland [Winner]
- Palo Duro Homes, Inc., Albuquerque, New Mexico [Winner]
- Transformations, Inc., Townsend, Massachusetts [Winner]

**Affordable Builders**
- Mandalay Homes, Phoenix, Arizona [Grand Winner] (Figure 8)
- Ithaca Neighborhood Housing Services, Ithaca, New York [Winner]
- Manatee County Habitat for Humanity, Bradenton, Florida [Winner]
- TC Legend Homes, Bellingham, Washington [Winner]

The Home Performance with ENERGY STAR Participating Contractors award is presented to participating contractors who have demonstrated innovative business practices that mark them as leaders among their peers. They exhibit outstanding professionalism, build strong customer relationships, and apply building science solutions to improve homes. Only contractors that take part in...
rigorous training, apply the whole-house approach, adhere to program requirements, and continuously improve their workmanship through quality assurance measures can engage with Home Performance with ENERGY STAR as participating contractors. Winners for 2013 are:

- Energy Efficiencies Solutions, Winsor, Connecticut [Winner]
  Customer Relations and Market Leadership
- Halco, Phelps, Connecticut [Winner]
  Market Leadership, Energy Savings, and Sales and Marketing
- Insulation Technologies, Milwaukee, Wisconsin [Winner]
  Customer Relations and Energy Savings
- Powersmith Home Energy Solutions, Copiague, New York [Winner]
  Market Leadership, Energy Savings, and Sales and Marketing

The Excellence in Building Science Education Award was presented jointly by the National Consortium of Housing Research Centers (NCHRC) and the Energy Department to advance the state of building science curricula across the United States and Canada. Patrick Huelman, an Associate Extension Professor in the Department of Bioproducts and Biosystems Engineering at the University of Minnesota, is being recognized for his exemplary work teaching building science and preparing a generation to produce buildings that are energy efficient, healthy, comfortable, and durable.

Building America Top Innovation recipients were acknowledged for their game changing Building America research achievements. These innovations are helping to guide residential building professionals in moving toward more energy-efficient, healthier, and durable homes.

**Advanced Technologies and Practices**

- **High-Performance Ducts:**
  Consortium for Advanced Residential Buildings, Norwalk, Connecticut [Winner]
- **High-Efficiency Furnace Blower:**
  Lawrence Berkeley National Laboratory, Berkeley, California [Winner]
- **High-Efficiency Window A/C:**
  National Renewable Energy Laboratory, Golden, Colorado [Winner]
- **Next Generation Advanced Framing:**
  Partnership for Home Innovation, Upper Malboro, Maryland [Winner]

**House-as-a-System Business Case**

Zero Net-Energy Ready Single Family Homes:

- Alliance for Residential Building Innovation, Davis, California [Winner]
- Building America Partnership for Improved Residential Construction, Orlando, Florida [Winner]
- Building Science Corporation, Somerville, Washington [Winner]
- Consortium for Advanced Residential Buildings, Norwalk, Connecticut [Winner]

Figure 7. “The Hale Plan” by New Town Builders of Denver, Colorado – 2013 Grand Winner, Production Builder. Home’s HERS Index, after solar PV, is 3. Every home New Town built at the Stapleton development in Denver will earn a Challenge Home certification from the US Department of Energy showing that it is a zero energy-ready home with a super-efficient building shell and a minimum of 2.5 kW of solar photovoltaic panels installed. Information and photo from http://www1.eere.energy.gov/buildings/residential/pdfs/ba_ch_newtown_100213.pdf.

Figure 8. Interior shot of Mandalay Homes project, Phoenix, Arizona, 2013 Grand Winner, Affordable Builders. The underside of the home’s roof is covered with 5.5 inches (R-20) of closed-cell spray foam, which provides a protected attic space to shield the HVAC equipment from the extreme heat of a Phoenix summer. The walls are filled with 3.5 inches of closed-cell spray foam, which provides excellent insulating and air-sealing properties. windows are double pane and vinyl framed with low-emissivity coatings to reduce heat loss in winter and minimize heat gain in summer. The house has fewer windows on the west side to reduce solar heat gain. Information and photo from http://www1.eere.energy.gov/buildings/residential/pdfs/bo_ch_mandalay_100213.pdf.
**Effective Guidance and Tools**

Window Replacement, Rehabilitation & Repair Guide:
- Building Science Corporation, Somerville, Washington [Winner]
- NorthernSTAR Building America Partnership, St. Paul, Minnesota [Winner]
- Partnership for Home Innovation, Upper Marlboro, Maryland [Winner]

Quality Management System Guidelines:
- Building Science Corporation, Somerville, Washington [Winner]
- IBACOS, Pittsburgh, Pennsylvania [Winner]
- Partnership for Home Innovation, Upper Marlboro, Maryland [Winner]
- Building America Solution Center:
- Pacific Northwest National Laboratory, Richland, Washington [Winner]

Exterior Rigid Insulation Best Practices
- Building Science Corporation, Somerville, Washington [Winner]
- NorthernSTAR Building America Partnership, St. Paul, Minnesota [Winner]
- Partnership for Home Innovation, Upper Marlboro, Maryland [Winner]

**Infrastructure Development**

- Standardized Data Sharing System (HPXML)
- National Renewable Energy Laboratory, Golden, Colorado [Winner]


**LEED v4 to Debut this November**

Leadership in Energy and Environmental Design (LEED) Version 4 (v4) will officially make its entrance this month at the Greenbuild® International Conference and Expo, held November 20-22, 2013, in Philadelphia, Pennsylvania. Registration, tools, and support resources under LEED v4 will become available at the Conference. Projects may continue to be registered under LEED 2009 until June 1, 2015. Beginning in the spring of 2014, LEED AP exams will be updated to reflect the new v4 criteria, however currently credentialed LEED AP’s will not need to retest.

For more information on LEED v4, visit [http://www.usgbc.org/leed/v4/](http://www.usgbc.org/leed/v4/).

The US Green Building Council’s® (USGBC) Greenbuild International Conference and Expo, held for 2013 at the Pennsylvania Convention Center, is the world’s largest conference dedicated to green building. Early sessions, including LEED workshops, will convene November 18 and November 19, 2013, at the Conference site. The 2013 Conference features Former Secretary of State Hillary Rodham Clinton giving the keynote address. Education tracks for 2013 will look at themes including affordable housing, net-zero, and community transformation. Scheduled Master Speakers include Ron Finley, Edward Mazria, Sheryl WuDunn, Joe Van Belleghem, and Avery Bang. The 2012 Conference had nearly 25,000 attendees from 90 countries. Conference agenda includes education sessions, green building tours and networking, and an exposition displaying the latest technological innovations and cutting-edge products. For more information on the Conference, go to [http://www.greenbuildexpo.org/Home.aspx](http://www.greenbuildexpo.org/Home.aspx).

**Building Technologies Office Sends RFI on Prioritization Tool**

The US Department of Energy’s (DOE) Building Technologies Office (BTO) has issued a request for information (RFI) seeking feedback from industry, academia, research laboratories, government agencies, and other interested stakeholders for the Prioritization Tool. The BTO developed the Prioritization Tool to improve its programmatic decision-making. The tool provides an objective framework for most energy-saving measures and scenarios, as well as methodology, comparing long-term benefits and end-user costs applied to various markets, end-uses, and lifetimes. To date, the tool contains data on over 500 energy efficiency measures along with their markets. It has the capability to perform extensive analyses using established methodology for calculating energy savings potential and the costs of conserved energy associated with each measure.

Announced via a press release on October 25, 2013, BTO seeks comments and information related to the Prioritization Tool that improves both the tool’s accuracy and applicability for technology planning within BTO. Specifically, BTO’s RFI solicits comments and information on data, assumptions and outputs of various energy efficiency technologies, and activities analyzed by the Prioritization Tool.

The BTO goal for the Prioritization Tool is to enable open and objective comparison of hundreds of technology and market-based investment opportunities available to BTO. The energy efficiency measures identified in the tool cover a spectrum of market opportunities, including...
residential and commercial buildings, new and existing buildings, as well as industrial and outdoor applications. Most of the measures considered fall within one of BTO’s main focus areas in building energy end-use sectors:

- Heating, ventilation, and air-conditioning (HVAC)
- Water heating
- Appliances
- Lighting
- Windows
- Envelope: insulation and roofing
- Sensors and controls
- Miscellaneous electric loads

The tool strives to be comprehensive by including most known energy efficiency measures proven to save energy; laboratory-demonstrated, field-tested, analytically derived (with peer review) savings, and inclusive by integrating inputs from hundreds of sources and expert reviews.

For further details, go to https://eere-exchange.energy.gov/Default.aspx?Search=prioritization%20tool&SearchType=#FoaIdc83baeea-4a16-48fa-a123-7c03796b503b or e-mail questions to BTO_P_Tool_RFI@go.doe.gov. Responses must be received no later than 5:00 p.m. EDT on December 24, 2013.

**Building America Technical Reports and Energy Measure Guidelines Access**

To access 2013 recent releases and top-ranked Technical Reports and Energy Measure Guidelines from the US Department of Energy’s (DOE) Building America™ Program, use the following links:

For **DOE CHALLENGE HOME CASE STUDIES**:

Download full set of 21 case studies in a zip file:


For **BUILDING AMERICA TOP INNOVATION 2013 PROFILES**:

Download full set of 10 profiles in a zip file:


---

**IN PRACTICE**

**Perspectives on Next Steps in Residential Energy Efficiency (Part 1)**

**A Conversation with Linda LaCroix, Aspen Construction Services**

“If you ask five people what sustainability means to them, you’ll get five different answers, but if you ask what makes a building sustainable, you may just get the same answer – energy efficiency,” began Linda L. LaCroix, Partner at Aspen Construction Services and Vermont State Representative to the National Association of Home Builders® (NAHB).

“One way to understand sustainability is as a capacity to maintain existing conditions over time. Resilience may be more what we are after – resilience might mean the

---

*Figure 9. The Roxbury House in the Catskills. The log home was certified at the Emerald level in energy efficiency, under the National Association of Home Builders® (NAHB) Green Building Standard. Photo courtesy Carolyn Bates.*
capacity to create synergies over time. The way to do that is to think of buildings as systems that interact with people and with nature – the primary systems being architectural and site design, use planning, the building envelope and interior spaces, air, water and thermal systems, energy, waste and water services, and the building’s sustainability system,” explained LaCroix.

Aspen’s project portfolio includes the Roxbury House, a net-zero ready energy efficient log home in the Catskills region of Upstate New York (see Figure 9). The log home is certified under the NAHB Green Building Standard at the Gold Level, earned the Emerald Level in energy efficiency, achieved a Five Star Plus ENERGY STAR® rating, and met Department of Energy’s (DOE) Builders Challenge. Unique project details include a geothermal heating system that delivers the building’s domestic hot water, heating, and cooling energy. The system includes a high efficiency, modulating gas boiler back-up for below zero degree days. The first floor walls are framed with D-log, which feature double-tongues with foam gaskets for air sealing. The thirty-foot high cathedral ceilings expose a dramatic view of the mountains: two floor to ceiling cypress trees built into the rear gable wall frame banks of windows and the French doors leading out to a stone patio (see Figure 10). Even with these challenges, the Roxbury House earned a HERS Rating Index of 48.

“When you achieve balance in human, built, and natural environments, you deliver the highest value – a desirable and resilient building that preserves resources and capital,” emphasized LaCroix. “Good design and site planning can do so much to increase performance - to bring the energy load down: if you start with a building that requires less energy, its energy, waste, and water systems can be crafted from less resources, both when they go in, and over their lifetime. Careful consideration of materials, sources, and methods are at the heart of an economical and beneficial construction – you achieve a great deal of performance here, and the trick is to focus on best systems blends because you can create synergies between components.”

“For example, we incorporated a green roof in a great little Pavilion project that our company recently delivered. The roof stabilized the building, which means that it gives the building broader tolerances to changes in moisture. Wood moves less in a stable environment: if the moisture content dramatically increases or decreases, wood moves, splits, curls. Everything has energy, understanding how systems move energy through the building over time is the first step in achieving performance. It’s like Einstein said – if he had an hour to save the world, he would spend 59 minutes defining the problem and need only one minute to solve it,” said LaCroix.

“Yet, in an individual home, the answers to these questions are not always obvious,” said LaCroix. “Some of the improvements are not mechanical, or based on insulation levels; some improvements are in simple products. The Roxbury House is an example of what can be achieved with a systems approach – one that brings design, building science, and services together, to achieve fabulous performance in what should be a low-performing structure – an 8” D-Log home. There are hundreds of details that contributed to a better result.” (See Figure 11.)

Details. The Roxbury House has dovetailed corners that pull together over time instead of mov-
The building envelope team improved thermal, air, and water performance prior to applying wall coverings by taking thermal images to uncover weaknesses in the envelope (see Figure 12), and the HVAC team worked with the mason and design team to smooth the effects of the mechanical kitchen hood and the air exchanges that are part of masonry structures – there are two masonry stone fireplaces in the home, one with a 54” opening (see Figure 13). Uneven air movement can impair the efficiency of air-sourced heating and cooling systems, but can aid in good airflow if considered during system design.

The Roxbury House has both radiant heat and forced air distribution systems – radiant in the first floor deck coupled with an air source that delivers heating and cooling, and helps level out humidity levels (the system maintains a constant humidity). Two air ducts incorporated in to the large fireplace, behind two hand-forged iron grates, deliver targeted air flow to a north-facing corner. The energy recovery ventilation (ERV) system also plays an important part in gaining efficiencies for the two distribution systems.

The building’s thermal energy is principally fueled by a geothermal system supplied by three 500-foot vertical bores, spaced thirty feet apart. The system provides space heating and cooling with full hot water supply. Aspen worked with a geothermal equipment manufacturer from Canada to accept their first installation of a combined heat pump and air handler. “These kinds of partnerships benefit everyone,” offered LaCroix, “and are important pieces to testing systems in real environments. Plus, the investment from the manufacturer leads to a stronger working relationship.”

“Our customers get it,” said LaCroix. “We like pushing the edge with companies wanting to prove their innovations, and we enjoy the opportunity of installing things for the first time. We prefer to see each structure as a prototype of unique integrations. Even in production building, houses are individual labs; each is situated differently and has its own unique site conditions and opportunities.”

“Combining space conditioning and hot water also created internal efficiencies,” summarized LaCroix. “The combo unit means that the mechanical system works less, reduces general wear and tear, takes up less space, uses less materials, and does more of what it is supposed to do, for less.”

For subscriptions call 1-800-638-8437 or visit our Web site at www.aspenpublishers.com
“If you were to take a thermal image of the tubes running through the floor, you would see two stripes of heat in the bay, and in between, a bunch of cold air. This is not a very efficient picture, as cold air in the bay fights with heated water in the tubes to equalize in temperature, meaning you need to compensate for the influence of the cold by running hotter water.” Instead, the GRAFIHX membrane allows the heat from the tubes to conduct throughout the floor bay.

The Roxbury House features another innovation that changes the way radiant distribution systems are installed. GRAFIHX™ (http://graftechaeet.com/GRAFIHX/GRAFIHX-Home.aspx), a graphite impregnated flexible cloth (see Figure 14) that conducts heat, is used to bolster the performance of the radiant floor heat distribution system. GRAFIHX comes in rolls, and can be easily cut.

“In a typical radiant heating system, we create heat by running hot water through flexible tubing pushed through aluminum plates installed either underneath, or on top of the floor deck,” explained LaCroix. “The radiant floor tubing connects to the hot water source through circulator pumps.”

The radiant tubing is free-stapled in the bays between a “sandwich” of GRAFIHX (see Figure 15). LaCroix explains, “The graphite material is a passive boost to performance because it spreads the heat outward from the tubing across the whole bay. This simple system allows us to lower the temperature of the water going through the tubes, and so outperforms traditional extruded aluminum plate systems. The materials cost about 50% less, and installation labor is a lot less because the worker doesn’t have to push the tubing through the rigid plates. Both short and long term goals are met.”

Next month, we’ll continue our conversation with LaCroix. To learn more about Aspen Construction Services, and to view videos documenting Roxbury’s construction, go to http://www.aspenvermont.com/portfolio_item/roxbury-energy-efficient-log-home/.

IN REFERENCE

Tips on Homeowner Education

Homeowner education is a facet of green building that receives little press; yet it is a growing mandate within various green building certification programs. In residential building, the ANSI-approved International Code Council (ICC) 700 National Green Building Standard® (NGBS) requires homeowner education (Operation, Maintenance, and Building Owner Education) as one of six mandated divisions within the Standard. For a project to become Green Certified, a minimum score must be achieved in each category, with the point total requirements increasing for successively higher levels of green certification (Bronze, Silver, Gold, or Emerald). Under Leadership in Energy and Environmental Design® (LEED) Version 4 (v4), education of homeowner, tenant, or building manager is encompassed within Energy and Atmosphere (EA) credits.

“Assembling LEED and NGBS-required homeowner education manuals is a little-attentioned area of the green home certification process,” reiterated Marla Esser, NAHB Certified Green Professional, LEED AP, and owner and principal of Sustaining Spaces, LLC. “The importance of homeowner education is great, especially around green certified homes. So many questions come up in the process of living in a space, and it all comes back to education. Think of the requirement for homeowner manuals in green certification processes as an opportunity not to be missed. How can we take the education mandate and make something really useful that a homeowner will continue to use?”

Esser addressed this topic September 20, 2013, presenting “Best Practices in Delivering the LEED and NGBS-required Owner Education.”
Start thinking about the staggering number of components in a home,” Esser said. “How much information do you have to know to operate a system, maintain it, or fix a problem? High performance homes have very specialized systems, components, special filters and different things that have to be done for maintenance.” (Refer to Figure 16.)

For the builder, a homeowner’s manual can manage the information overload of home ownership, offer common maintenance solutions, and reiterate to customers the “what and why” of their purchase. The best homeowner education tool will be easily accessible, and should communicate with clients about really critical areas of maintenance in their home, so a homeowner can enjoy and take care of the final product.

“Be your client’s superhero,” emphasized Esser. “Homeowner education means giving the homeowner the power to protect one of their biggest investments – their home.”

Assembling homeowner manuals for green certified homes

Homeowner education can be delivered in many forms: via a printed manual, from electronic files, through a software module, or by an online application, such as a builder’s system portal. Above all, the information should be as user-friendly and as accessible as possible.

For Esser, any homeowner education tool must encompass information on a home’s components. “Unfortunately, there’s not a lot of standardization by manufacturers on how product information is delivered, even across brands,” Esser said. Home component sections should include a full inventory and product information, as well as home and landscape plans, but should go beyond standard lists to cover various resources. “For example, include information on energy, water, and resource efficiencies, ways to reduce pollutants in the home, and moisture maintenance information and checklists,” explained Esser. “Also, include what is available in the surrounding community, such as hazardous material recycling locations, or local green power companies.”

Homeowner education is a component that is very important for the ongoing efficiency and maintenance of the home. Nevertheless, an inventory of home components – from major systems, to appliances, to fixtures – which may include research specifications, warranty information, and advice on care, can be major source of information overload to the homeowner, and presents a daunting organizational challenge to the builder. “Think major systems, and work through these major systems to their smaller components,” advised Esser. “Go from the building envelope and down from there.” Esser recommended helping owners register for the warranty on their products and including pictures of things like the label on paint cans, and what bulbs were used in fixtures, as a powerful value-added piece.

A second component for the manual, and vital to the homeowner, is constructing a guide to maintenance solutions. “This should be the first thing that comes to mind when I say ‘homeowner’s manual’,” stressed Esser. This section should cover common maintenance solutions for home ownership, including maintenance and checklists for safety and health, seasonal issues and checklists, and required maintenance to retain the green attributes of a home and its systems. “Think of this section as enabling owners to solve little prob-
lems themselves,” Esser said. Home specific resources should contain a diagram of safety valves and controls, and things such as emergency shut-off protocols, frost-protected shallow foundations, local service providers for maintenance and services, and can account, via photo record, of framing with utility locations. (Refer to Figure 17.)

Homeowner education should also communicate green building “proof.” “This is the section where you demonstrate to the homeowner that you did exactly what you said you would do,” Esser noted. Documents to include are the final green building certificate, or a placeholder before final inspection; forms, checklists, and inspection lists; and a list of green building features (for further suggestions, see NGBS 1001.1 and LEED 1.1 i,ii,iii). “The best information will include green or energy efficient features in a format that the homeowner can understand,” Esser said. “For example, explain that high quality insulation was selected to provide for a warm, quality home, then detail the particular insulation brand’s specifications. A homeowner wants to know what the home will actually provide for them, based on specifications and features?” From an organizational standpoint, Esser recommended listing green features by areas, categorizing them into groups, such as the home’s envelope, or mechanical systems.

After creating a home’s components and a certification section, Esser recommends constructing a resources section. “Resources are great, because you can do these once and then rinse and repeat. Almost 90% or more of the information here will apply to all homes.” For Esser, resource guides can become the most powerful education piece in a whole homeowner education package or manual. The section should contain advice on how to save money on repairs, how to conserve utilities, recommended replacements, and ultimately should help reduce the total cost of home ownership. “You might want to list local recycling programs, green options for landscaping, local utility programs with renewable energy or credits, the benefits of high-efficiency lighting, water and energy conserving practices, and local transportation locations,” said Esser. (For further suggestions, refer to NGBS 1001.1 (4)-(8); LEED 1.1 (a) v, vii, viii.)

In summary, a homeowner education tool should cover these major pieces:

- Green certifications and a home’s product list;
- Major systems, appliances, and components;
- Home maintenance and operational checklists, including care specific to green and energy efficient living;
- Emergency utility information; and,
- Contractor contact information.

“Think of your homeowner’s manual as the place for all things home,” concluded Esser.

Marla Esser is the owner and principal of Sustaining Spaces, LLC (http://www.sustainingspaces.com/), offering green consulting, education, and marketing support for the home industry and consumers. Sustaining Spaces’ online home management system, HomeNav® helps people better operate and maintain their homes and residential properties. “A Guide to Assembling Homeowner’s Manuals for Green Clients” was released October 2013, email marla@HomeNav.com for availability.

Marla has worked on a number of green home projects including a green certified (National Green Building Certification) remodel of 40 townhomes in St. Charles, MO with LITC financing, Extreme Makeover: Home Edition home certified green in St. Louis metro, St. Louis Designers Green Showhouse, and Habitat for Humanity homes in St. Louis, St. Charles, and Jefferson City, Missouri. Current projects include new green homes for a Missouri community action agency and green remodel projects in the St. Louis County Neighborhood Stabilization Program. She is a steering council member of the St. Louis Home Builders Association Green Building Council, the St. Louis USGBC chapter, and the Greening Midwest Communities conference.

To view Esser’s recorded webinar, visit http://green-expo365.com/en/continuing_education/.