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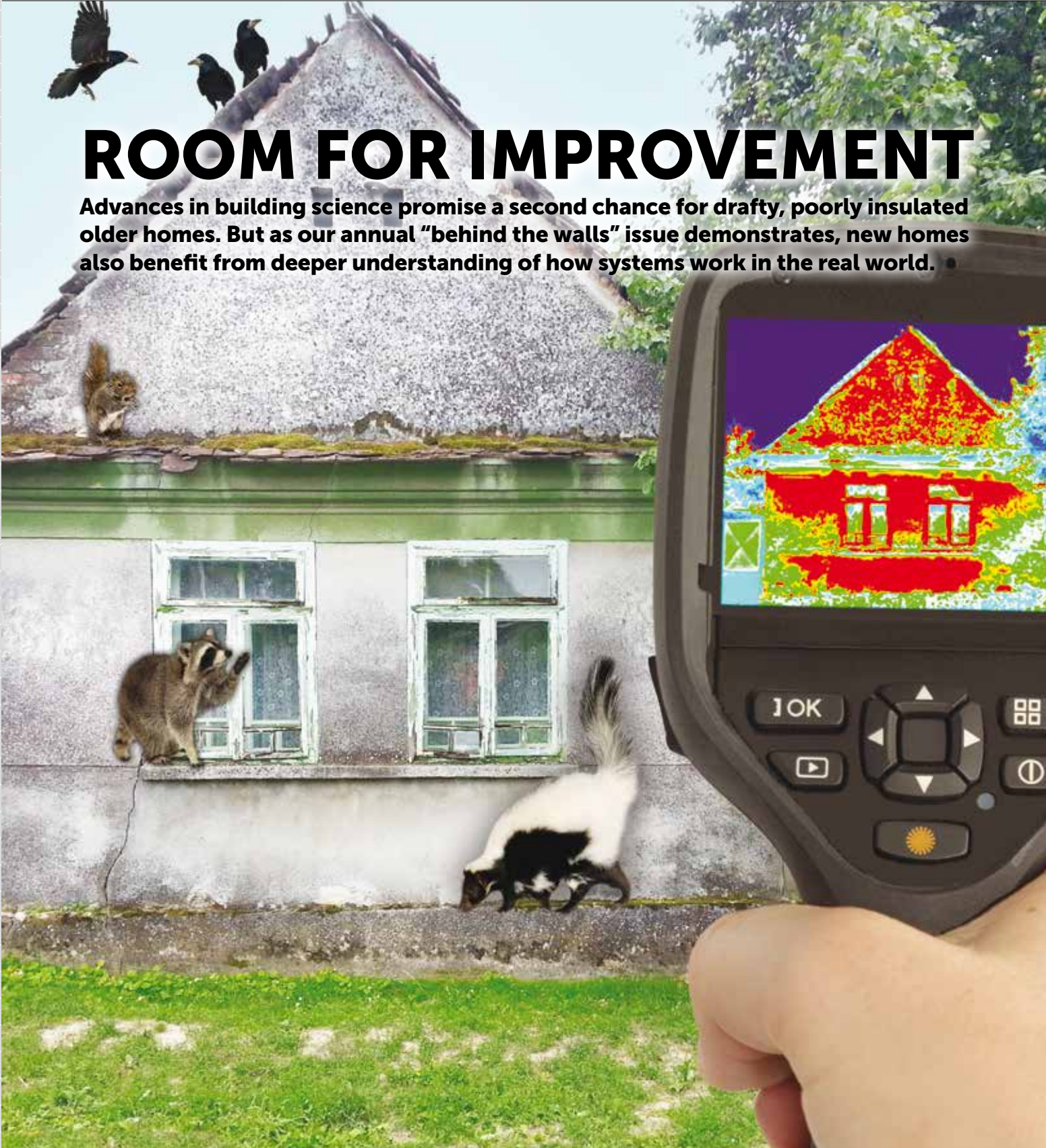
INSIDE:
BOSCH
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Mini-Tank
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GreenBuilder®

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Advances in building science promise a second chance for drafty, poorly insulated older homes. But as our annual "behind the walls" issue demonstrates, new homes also benefit from deeper understanding of how systems work in the real world.



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Green Builder® Media Takes the Gold

BEST TRADE MAGAZINE & BEST WEBSITE

For the third year running, Green Builder® Media has emerged as the best trade magazine in a competition including such heavy hitters as *Inman News*, *The Wall Street Journal* and *The New York Times*. The company was presented with both the Best Residential Trade Magazine Gold Award and the Best Web Site Gold Award in the 65th Annual Journalism Awards, recognizing excellence in reporting, writing and editing stories about residential and commercial real estate.

Currently celebrating its 10th anniversary leading the charge for more sustainable building—both making and reporting on the news in the green building and sustainable living space—Green Builder® Media proves its mettle by consistently being chosen as a standout publication, delivering authoritative content that helps building professionals create the most sustainable built world possible.

"We were especially pleased about this year's win, because it included our year-long Celestia Project, our vision of living abundantly in the year 2100," says *Green Builder* Editor-in-Chief Matt Power. "We took a lot of risks making forecasts and predictions, but they seemed to resonate with both our print and online readers."

"While our staff is excited about the print win," Power adds, "we're just as thrilled that our online efforts—content marketing, ebooks and custom content—got such great kudos. We're carving out whole new publishing frontiers."



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Zero Net Energy Mandates: The Upside of Reactionary Politics

New, strict construction rules in California, Austin and elsewhere have their roots in the politics of austerity.

THIS MONTH, I wrote about a large geothermal installation in Washington called Badger Mountain, where a 5,000-unit master community is putting in thousands of geothermal ground loops. That's a big development, embracing green technology on a scale I've rarely seen in 20 years of covering the building industry. What changed?

I have a theory. See if you agree.

We know California's addition of a Zero Net Energy (ZNE) requirement to their Title 24 building regulation last year had something to do with the shift. That move has already seen ripple effects across the country, as the new model energy code is adopted quickly across other states. It's increasingly likely that performance-based codes that require homes to produce as much energy as they consume



will become a residential "norm" in most parts of the U.S. Austin, for example, has already taken the 2020 goal up a notch, requiring net-zero capability for any home build after 2015.

The sudden embrace of ZNE is no accident. But it may not be what its instigators had in mind. Sure, the federal government has had fairly aggressive ZNE standards in place for new commercial buildings for a while now. But the commercial and residential sectors have

operated quite independently of each other for decades.

Not so much, anymore. Federal political posturing by anti-tax, anti-spending groups such as the Tea Party are bleeding over into regional decision making. Several years of blocking President Obama's federal infrastructure spending have had a crushing effect on many state budgets. They must get by with drastically less money for infrastructure than they need to maintain existing roads—let alone build new ones, add and update sewage lines, or implement any of the other key components required by new construction.

Think about it. If you were a governor or a mayor, how would you address this huge funding shortfall? You would require buildings to pay their own way. The only good new home in a world of "no new taxes" is one that comes with its own infrastructure—yet will still produce new taxable property. That's a zero-net-energy home.

A few prescient corporations have seen the shift coming. They're stepping up to create ancillary businesses (such as solar leasing and geothermal loop services) that absorb the added costs for builders who need to get quickly to net-zero compliance. It's proving to be a fast track to builder adoption of alternative technologies.

So next time you read about a new solar community, geothermal community or energy code mandate, thank a Tea Partier. Making the oil industry *less relevant* may not be what the anti-government Koch Brothers had in mind, but it could be the outcome they will be remembered for, in the solar-powered history e-book downloads of families living in tomorrow's geothermal homes. —MP

A Sharp Drop in Government Infrastructure Spending

U.S. Real Government Non-Defense Spending on Structures



CREDIT: BCA RESEARCH

Infrastructure Blues. Although this chart is a bit dated, it gives you an idea of how infrastructure spending in the U.S. has dropped off over the last few years.

THIS MONTH'S GIVEAWAY



BOSCH
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Enter to Win a Bosch Tronic 3000T Mini-Tank Water Heater

The Bosch Tronic 3000T is a 2-1/2 gallon point-of-use electric mini-tank that can be wall hung (bracket included) or floor mounted. Simply tap into the cold water line and install the water heater directly at the sink to provide hot water. It may also be installed in-line with a larger hot water source to eliminate the wait for hot water. Requires 120 V 1440 W plug-in electrical connection.

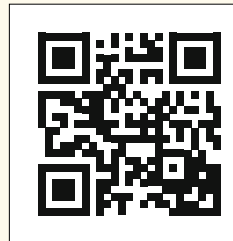
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FIELD REPORT

News About Sustainability Issues and Green Products

Resilience AmericaCorps Announced

A new public-private partnership will help build resilience in communities affected by climate change.

A NEW PUBLIC-PRIVATE partnership will help build resilience in communities across the country. Part of President Obama's Climate Action Plan, Resilience AmeriCorps will help local leaders respond to disasters, including extreme weather events. The two-year pilot program, which launches later this year, will recruit, train and embed VISTA (Volunteers in Service to America) volunteers in up to 12 communities, focusing on those that will be disproportionately affected by climate change. The multi-agency initiative will build volunteer networks to carry out program initiatives and create education and outreach



materials to strengthen awareness and citizen engagement in low-income communities.

The program is a collaborative effort between the Department of Energy (DOE), the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the Corporation for National and Community Service (CNCS) and Cities of Service, with support from the Rockefeller Foundation. On a related note, the Dept. of Housing and Urban Development (HUD) is hosting the National Disaster Resilience Competition (NDRC), designed to help states and local communities recover from past disasters while improving their ability to withstand future extreme events through strategic community investments. Forty cities will submit proposals for specific projects.

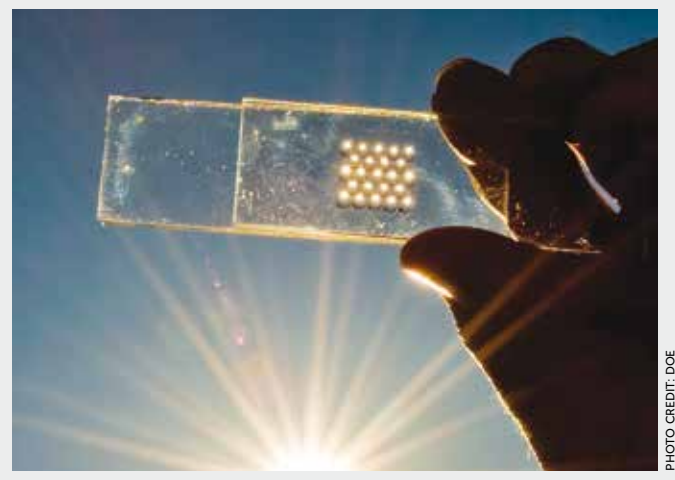
Learn more at: <http://1.usa.gov/1JRSTCY>

Army Develops Super-Thin Solar Cells

The U.S. Army has patented a thin, durable solar cell that is more efficient than existing thin-cell technology.

RESearchers at the U.S. Army's Redstone Arsenal in Alabama have developed super-thin solar cells that are just a few hundred nanometers thick. These cells are nearly 1,000 times thinner than even the thinnest solar cell technology available today, including the tiny cells developed at the Sandia National Laboratory (pictured). The Army developed the technology by inserting thin layers of heavy metals such as gold and silver in between semiconductor layers, usually silicon. This "sandwich" creates a larger band gap, which allows a larger percentage of incoming sunlight to be converted into electricity.

"The key to the development of efficient, compact solar cells is advances in nanotechnology, nano-fabrication techniques and thin-film production," says Dr. Michael Scalora, a research physicist at the U.S. Army Aviation and Missile Research, Development and Engineering Center (AMRDEC) and co-inventor of the cell. Not only are these cells thinner and lighter,



they are more durable and less subject to damage by UV and infrared light.

Learn more at: <http://1.usa.gov/1Kalijl>

PHOTO CREDIT: DOE

FLYING HIGH WITH BIOFUELS

Red Rock Biofuels has signed long-term contracts with both Southwest Airlines and FedEx Express.

THIS FALL, RED ROCK BIOFUELS LLC will break ground on the first of three commercial biofuel refineries. The plant, located in Lakeview, Ore., will convert 140,000 dry tons of woody biomass into synthetic jet fuel, diesel and naphtha. Last September, Southwest Airlines contracted with Red Rock to begin supplying them with 3 million gallons of synthetic jet fuel per year, starting in 2016. The airline plans to use the biofuel, which will be blended in a 50/50 mix with regular jet fuel, in the company's San Francisco Bay Area operations. More recently, FedEx Express signed an eight-year contract with Red Rock to purchase 3 million gallons of biofuel annually, starting in 2017.

Synthetic jet fuel is a lower-carbon, renewable alternative to fossil fuels. Red Rock Biofuels will source much of the woody material for its Lakeview operation from forest thinning operations nearby. Gasification of this woody biomass produces synthesis gas, or "syngas," which is then



CREDIT: DYLAN ASHE

converted to liquid hydrocarbons and further refined to produce the different fuel types. The Lakeview plant is funded in part by a \$70 million grant from the U.S. Departments of Energy, Agriculture and Navy.

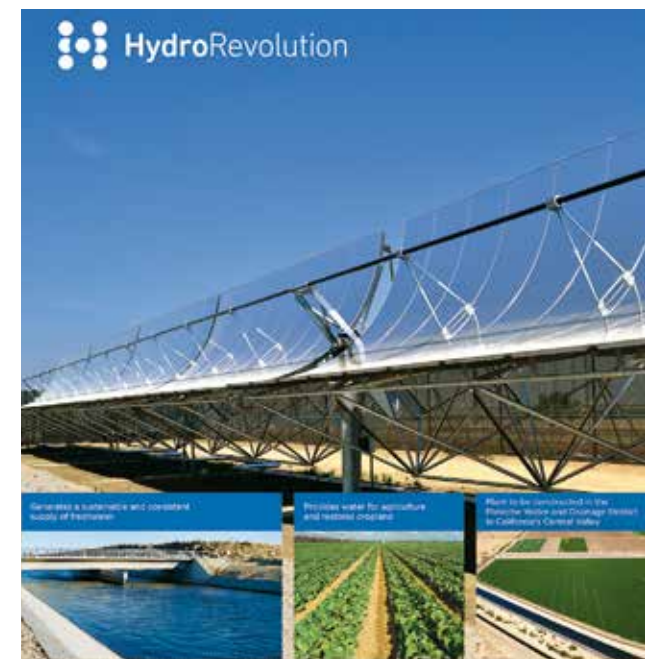
Learn more at: <http://bit.ly/1U6kGkV>

Solar-Powered Desal Plant to Come Online

A solar-powered desalination plant expands after a successful demonstration project.

HYDROREOLUTION, A SUBSIDIARY OF WaterFX, announced this July that it plans to build a solar-powered desalination plant in the Panoche Water and Drainage District in California's Central Valley. The plant will use its Aqua4 technology to recover freshwater from unusable, salt-compromised drainage water. The system consists of a concentrated solar thermal array which heats mineral oil; the oil transfers the heat to the multi-effect distillation system, which recovers 90 percent of the freshwater from the source water. The concentrated salts and minerals are recovered as usable products.

The plant is an expansion of a successful demonstration plant that was installed in the same district two years ago. The HydroRevolution plant will occupy 35 acres but will expand to 70 acres—a fraction of the land currently used to manage and reuse irrigation water. Eventually, the new plant should be able to treat 5,000 acre-feet of water per year, enough to supply 10,000 homes or 2,000 acres of cropland.



WaterFX builds and operates distributed water reuse systems powered by renewable energy.

Learn more at <http://waterfx.co/hydrorevolution>



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Laminated house wraps, like TYPAR®, a PGI Brand, come with a thin, fragile film layer to keep air and water out. But they can easily scratch and tear during the installation process, allowing water in the walls which can lead to exterior wall damage. DuPont™ Tyvek® weather barriers are made with a unique material that provides superior performance for keeping air and rain out while letting moisture escape. So don't settle for less. Whether you're building a new home, or residing or remodeling an existing one, insist on Tyvek® for superior weather protection. It's no fairy tale.

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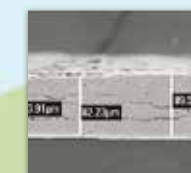
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TYPAR®, a PGI Brand, like other laminated house wraps, is comprised of a thin film coating on a mesh backing. The thin film layer is very delicate and can be easily damaged on the job site. Once damaged, the functional layer, which can vary from 4.8 to 22.6 microns in thickness, no longer provides adequate resistance to air and water infiltration.



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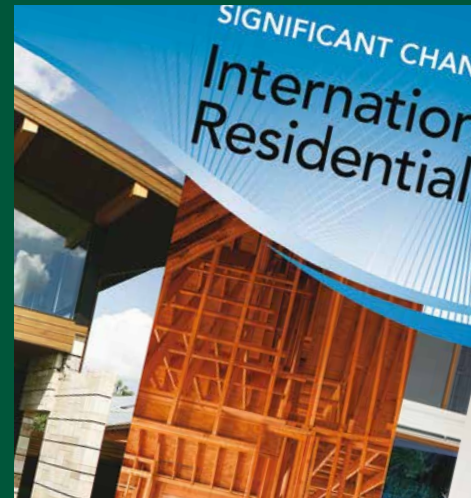
TYPAR® house wraps consist of a thin, functional film coating on a structural mesh.

The electron micrographs show that DuPont™ Tyvek® HomeWrap® is uniquely engineered so its ability to resist air and water extends the full thickness of the product. Insist on DuPont™ Tyvek® for superior performance.

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Floor Framing Cavity Insulation

An excerpt from ICC's *Significant Changes to the International Residential Code® (2015)*, Chapter 11 Energy Efficiency.

Significant Changes to the IRC 2015 Edition

N1102.2.8, Table N1102.4.1.1 ■ Floor Framing Cavity 217

CHANGE TYPE: Modification

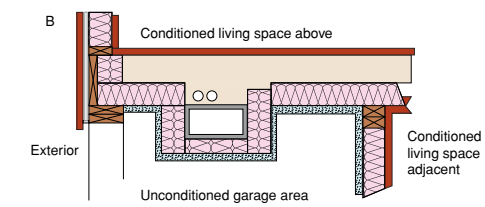
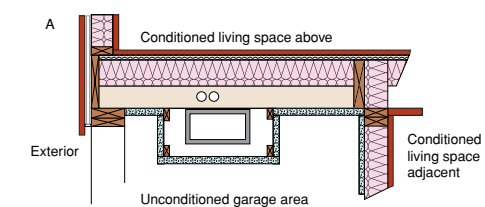
CHANGE SUMMARY: The code now permits an air space above required insulation installed in a floor framing cavity above unconditioned space. Table N1102.4.1.1 has been reformatted into three columns to separate the air barrier requirements from the insulation requirements.

2015 CODE: N1102.2.7 N1102.2.8 (R402.2.8) Floors. Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of the subfloor decking.

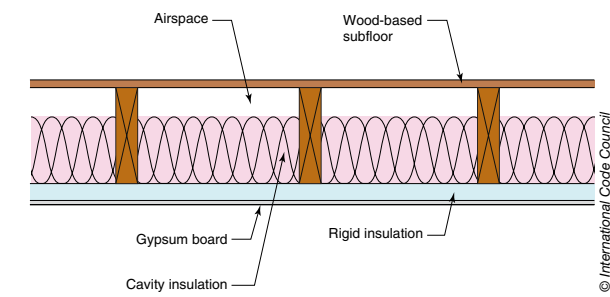
Exception: The floor framing cavity insulation shall be permitted to be in contact with the topside of sheathing or continuous insulation installed on the bottom side of floor framing where combined with

N1102.2.8, Table N1102.4.1.1 continues

N1102.2.8, Table N1102.4.1.1 Floor Framing Cavity Insulation



Two options for floor insulation above unconditioned space



Option for floor insulation above rigid insulation

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218 PART 4 ■ Energy Conservation

N1102.2.8, Table N1102.4.1.1
continued

TABLE N1102.4.1.1 (402.4.1.1) Air Barrier and Insulation Installation

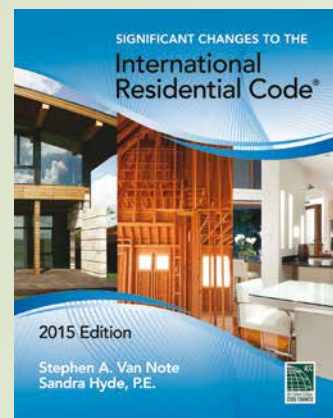
Component	Air Barrier Criteria	Insulation Installation Criteria
Floors (including above garage and cantilevered floors)	The air barrier shall be installed at any exposed edge of insulation	Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the topside of sheathing, or continuous insulation installed on the underside of floor framing; and extends from the bottom to the top of all perimeter floor framing members.

(Portions of table not shown for brevity and clarity.)

insulation that meets or exceeds the minimum wood frame wall R-value in Table N1102.1.2 and that extends from the bottom to the top of all perimeter floor framing members.

CHANGE SIGNIFICANCE: Previously, the code required insulation that was installed in a floor framing cavity to be in contact with the underside of the floor sheathing. The code still permits that as one option, but adds another option to have an air space between the floor sheathing and the top of the cavity insulation. In this case, the cavity insulation is in direct contact with the topside of the sheathing or continuous insulation installed on the underside of the floor framing and is combined with perimeter insulation that meets or exceeds the R-value requirements for walls. This second option leads to fewer cold spots and does not increase heat loss. It also facilitates ductwork, piping and wiring to be enclosed within the thermal envelope.

Previously, Table N1102.4.1.1 contained only two columns. The first column described the component of construction under consideration and the second column prescribed both the air barrier and insulation installation criteria. The 2015 IRC reformats the table to place the air barrier and insulation requirements in separate columns. The reformatting does not change the technical requirements but intends to clarify the application of the table and reduce confusion by code users.



Significant Changes to the International Residential Code® (2015) is a valuable tool for transitioning to the new code. The book lists the Change Type, Change Summary and Change Significance for the most important changes allowing readers to save substantial time learning new requirements. This publication may be purchased by visiting the ICC online store at www.iccsafe.org/GBchanges.



ICC NEWS RELEASE

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2015 IECC Adoption, Compliance Make New U.S. Homes More Energy Efficient

Use of the newest edition of ICC's energy code benefits code officials, home builders and homeowners

Adoption of the 2015 *International Energy Conservation Code (IECC)* will make compliance easier for new homes that are inspected for an Energy Ratings Index (ERI) under the Home Energy Rating System (HERS). As a result, code officials will have clear guidance on a home's energy efficiency rating, homebuilders will undergo fewer inspections and homeowners will get an easy-to-understand HERS Index label that shows the efficiency of their new home. The ERI performance path gives builders another option to comply with the 2015 IECC. The HERS rating is the existing compliant ERI method and nationally recognized for inspecting and calculating a home's energy performance.

The International Code Council (ICC) joined with RESNET the organization that created and certifies HERS ratings to help code officials and HERS raters work closely to achieve more efficient homes with less overlap and duplication of efforts. For more information on how the HERS Index applies to energy codes, view the video posted at <http://go.iccsafe.org/e/25182/1Cp7cMx/2k61cq/734316931>.

The U.S. Department of Energy (DOE) says use of the 2015 IECC would make new American homes about one percent more energy efficient than homes built to the 2012 IECC. While the increase in energy efficiency from the 2012 to the 2015 editions of the IECC is comparatively small, for states still using the 2009, 2006 or even an earlier code, the increase in energy efficiency could be as much as 30 percent.

The Code Council recommended DOE use a simple, checklist-style form for states to complete to ensure they have reviewed the new IECC, held a public hearing, and made a decision to update their state code or not, including reasoning as to why the decision was made. DOE indicated it would consider this proposal in efforts to monitor state compliance with the law requiring the state reviews. States have a two-year period to review the 2015 IECC and decide whether to update the state energy code to the level of the new code.

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ICC-SRCC Recognized by city of Los Angeles as Solar Heating and Cooling Listing Agency

ICC-SRCC certified products can now be used in the city

The city of Los Angeles Department of Buildings and Safety's Mechanical Testing Laboratory has approved the Solar Rating & Certification Corporation (ICC-SRCC) as a recognized listing agency for solar water heating products. As a result, ICC-SRCC certifications demonstrate the product complies with the city's 2014 plumbing code for solar water heaters. ICC-SRCC's Standard 100 is referenced for solar collectors. Its Standard 300 is referenced for solar water heating systems.

"Our listing agency recognition benefits code officials, inspectors, specifiers and manufacturers," said ICC-SRCC Executive Director Eileen Prado. "The listing increases the value of ICC-SRCC certifications by eliminating the need to seek other certifications to be installed in the city of Los Angeles. If the solar collector or solar water heating system has an SRCC mark, it can be used in the city."

ICC-SRCC's approval is granted under the provisions for Section 98.0503 of the Los Angeles Municipal Code. Solar manufacturers can apply for ICC-SRCC certification online at www.solar-rating.org.

ICC-SRCC is not the only member of the International Code Council Family of Companies recognized by the city of Los Angeles. Also on the list are ICC Evaluation Service (ICC-ES) listings for plumbing, mechanical and fuel gas products. ICC-ES is the only agency specifically referenced as an approved agency for building product evaluation under section 98.501 of the Los Angeles municipal code. And the International Accreditation Service is recognized by the city of Los Angeles Department of Building and Safety (LADBS) for complying with requirements of the LADBS Guidelines for Recognition of Listing/Product Certification Agencies for Plumbing, Mechanical and Fire Suppression Products.

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Public Comment Hearings
The Code Development Cycle begins with the 2018 I-Codes. Final changes to the codes will be decided through both in-person and online voting via ICC's cdpACCESS. This will be the first complete code cycle to use the new cdpACCESS cloud-based process.



Special Events and Activities
The line-up of special events include keynote speakers, special receptions, hospitality events, companion tours and more. **Don't miss the Resilience Workshop featured at the Government Relations Forum.**



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"The NorthernSTAR team analyzed two distinct temperature set point controls: (1) outdoor reset and/or turndown after the heating season and (2) space-heating modulation (water flow and airflow). Each increases system efficiency, improves occupant comfort, saves energy and simplifies the sizing and design process." (p. 26)

ON THE COVER

ROOM FOR IMPROVEMENT

Artist: Liza Kelley

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Panasonic

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Fine Tuning Net-Zero Practices

The DOE's Building America program partners are already demonstrating that it's possible to build zero-energy-ready homes today. The next challenge? Refining solutions, such as the application of extra-thick layers of exterior rigid insulation, and helping to drive code changes that support high-performance homes.

IN MAY OF THIS YEAR, the Department of Energy (DOE) announced it was investing another \$4 million to develop energy efficiency solutions for high-performance homes. Research teams in the DOE's Building America (BA) program will focus on three areas: high-performance building envelope assemblies and systems; optimal comfort systems for heating, cooling, air distribution and humidity control; and high-performance ventilation systems and indoor air quality strategies.

The DOE has made marked progress toward its goal of "doubling energy productivity of homes by 2030."

"We've demonstrated that production builders can build zero-energy-ready homes, and homes that are 30 to 50 percent more efficient than current code in all climates and at all price points," says Eric Werling, coordinator for the Building America program. "Now

we're working to make these solutions available to smaller builders."

But the low-hanging fruit is gone.

Many of the remaining technical challenges have come to the forefront precisely because homes *are* tighter: the need for ventilation systems that can adjust to outdoor conditions; affordable smart sensors that can detect indoor pollutants; and HVAC systems that are sized right for the smaller loads of high-performance homes, and that can better manage relative humidity. And, as Werling points out, not all of the challenges are technical. Codes are often one step behind techniques that enhance performance or improve indoor air quality.

Over the next several years, the newest BA teams will be working on these specific challenges. In the following pages, we've highlighted some of the solutions upon which this new research will build.

Industry Leader. Denver-based New Town Builders creates high-performance envelopes for DOE-certified Zero Energy Ready Homes using lumber-saving advanced framing techniques, which maximize the amount of space available in the walls for blown-in fiberglass insulation.

PHOTO CREDIT: NEW TOWN BUILDERS

Space Conditioning, Simplified

A study coordinated by Building Science Corporation demonstrates that ductless mini-split heat pumps are a viable strategy for production housing in cold climates.

ALTHOUGH MINI-SPLIT HEAT pumps (MSHPs) are more expensive on a per-ton basis compared to fully ducted conventional systems, they offer significant installed cost savings when distribution costs are taken into account. Building Science Corporation and Transformations, Inc. have demonstrated that simplified space conditioning distribution using MSHPs can provide excellent performance. However, there are some cases and situations that designers should be aware of as potential failures; in addition, occupant operation can impact performance.

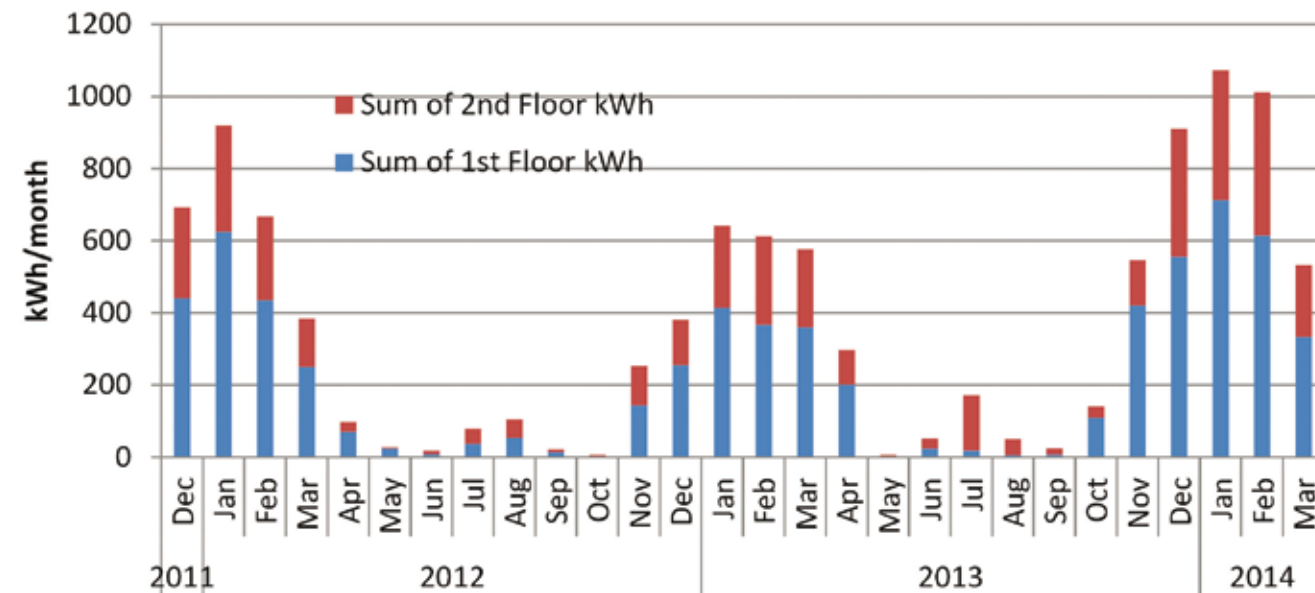
EVALUATING MSHP PERFORMANCE

Transformations, Inc. has been building net-zero houses in a variety of configurations throughout Massachusetts. Part of the

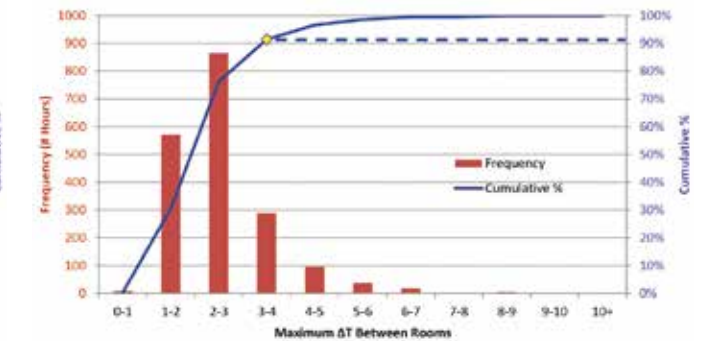
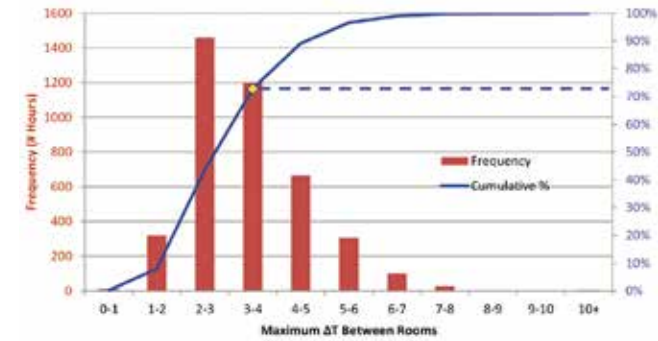


Transferred Savings. For a standard-size house, Transformations, Inc. saves \$5,500 by using a simplified MSHP system and spends \$15,000 on enclosure upgrades.

company's strategy is to use MSHPs with non-ducted heads mounted on walls, and to invest the savings in the building shell. Typically, the systems consist of a single point of heating or cooling on each floor. These simplified systems have been



Cumulative Data. As would be expected in a Zone 5A climate, heating consumption far outweighed cooling consumption.



Solid Performance. This sample data for one house from 2012-2013 shows that while the MSHP was operating in winter (left), temperature differences between rooms fell within 4° F 72 percent of the time. During the summer (right), over 90 percent of the hours fell within the acceptable range.

CREDIT: BUILDING SCIENCE CORPORATION

nearly trouble-free, with very few callbacks.

A cooperative study between Building Science Corporation and Transformations, Inc. monitored the performance and energy use of MSHPs in eight houses located in two subdivisions in Massachusetts. The scope of the monitoring packages included temperature and relative humidity (both interior and exterior), energy use and the open/closed status of interior doors.

The builder installed two models of Mitsubishi MSHPs: FE12NA series (1:1) and MXZ series (3:1) units. These units are rated down to -13 and retain their full heating capacity at -5°F —critical when relying on a heat pump as the sole heating source in a Zone 5 climate.

GENERAL PATTERNS

Taken as a whole, the MSHPs performed well. When a constant interior set point was used, the MSHP modulated up and down with outdoor temperature, running almost continuously throughout the winter to meet load. The first-floor unit provided the majority of the heating compared to the second-floor unit because of thermal buoyancy (heat rising to the second floor). Conversely, in summertime the second-floor unit often provided the majority of the cooling.

Equipment capacity and sizing. There were no issues with equipment sizing or lack of capacity, which indicates that these cold-temperature heat pumps are a viable strategy as a single heat source in cold climates. Monitoring confirmed that the MSHPs seldom hit maximum power draw, which suggests there was substantial excess capacity even during worst-case winter conditions.

Oversizing (compared to calculated loads) ranged from 150 to 200 percent. Oversizing MSHPs can be beneficial, since they modulate their capacity and reach their highest efficiency when running at the lower end of their capacity range.

Temperature distributions. The Air Conditioning Contractors of America recommends a maximum 4°F difference within a home or zone (highest minus lowest temperature), so temperature data were evaluated using this criterion. In winter, results ranged widely: during one winter, one house experienced temperature differences of 4°F or less just 19 percent of the

time; in the previous winter, 73 percent of the hours fell within the acceptable range. However, some weaknesses of this metric were pointed out. Data imply that summer conditions are less challenging than winter conditions for simplified distribution—at least given the solar gains (glazing ratios and solar heat gain coefficients) in these houses.

Door status effects. Previous work has shown that bedrooms during closed-door hours experienced greater temperature differences between hallways and bedrooms compared to open-door hours. Data from this study was inconclusive. Many of the houses had very few closed-door hours, and in another house, MSHPs were operated in an on/off manner (instead of using a constant set point), which rendered the door status data unusable.

SPECIFIC ISSUES

Thermal buoyancy affects distribution, even in very airtight houses at 1 ACH 50. Heating or cooling a two-story home with one MSHP will likely result in some discomfort during either the heating or cooling season, depending on the unit's location. In addition, the study revealed issues specific to individual houses:

Two-story houses with single MSHPs on first floor.

Due to their small loads, two small houses were equipped with a single MSHP on the first floor. However, during the first summer, the second floor did not cool down to set point (it was 10°F warmer than the first floor), even with the use of transfer fans. These issues are clearly due to thermal buoyancy; conditioned air rises from the first-floor unit in the winter but stays on the first floor during the cooling operation. An additional MSHP was retrofitted to the second floor, correcting this issue.

Open-plan first-floor temperature distributions.

In general, open-plan first floors had few issues. The few exceptions were caused by geometry and thermal buoyancy. In one house, an open stairwell intercepted heating air before it could reach across the space; in another, air leaking from a dryer vent resulted in a single cold room.

Bonus room comfort. In one house, the owners complained of a bedroom suite and a bonus room that were consistently

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Unwelcome Bonus. For one house, the MSHP system did not keep the bonus room warm enough. As the study points out, this problem had to do with the particular geometries of the house and should not be applied to bonus rooms generally.

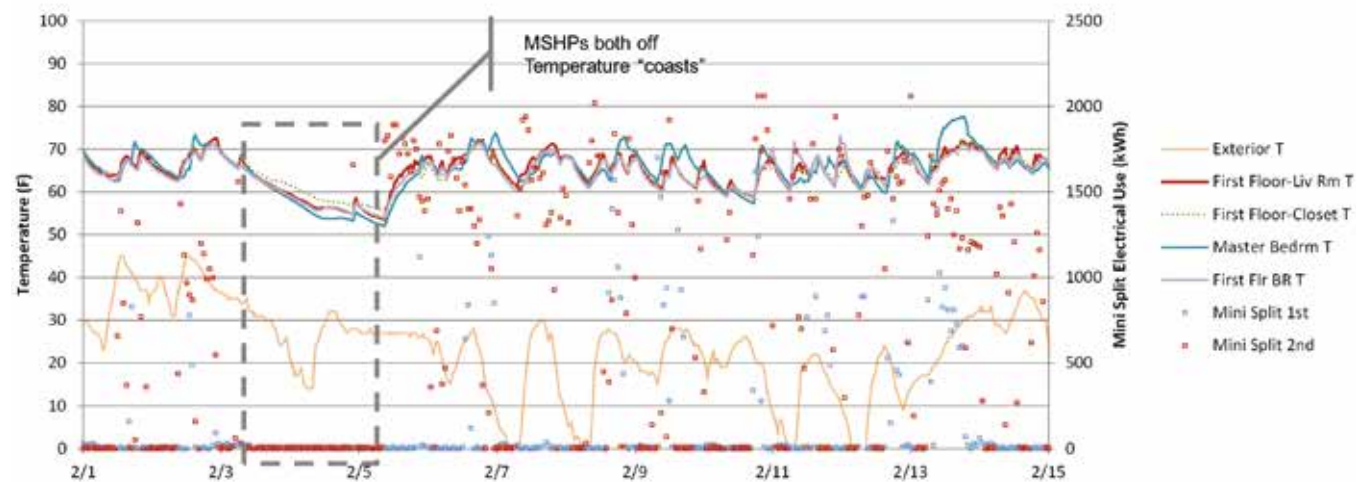
cold in wintertime. A constant set point was used, but leaving doors open was not compatible with their lifestyle and schedule. Monitoring confirmed that extended winter periods with closed doors resulted in temperatures in the high 50s in the bedroom suite and high 40s in the bonus room. This house was larger than other monitored houses and had “unfavorable geometries” in the problem areas. The bonus room, which was located above a garage, had exterior temperatures on five of its six sides. The problem was resolved by installing a 3:1 (indoor units: outdoor unit) MSHP with indoor heads in all three bedrooms.

It is worth noting that when the doors were left open, temperatures in the problem rooms rebounded quickly. Although they were still on the cool side (low- to mid-60s), this demonstrates how an open or closed door affects temperatures in the room.

In the future, the builder may switch to a small ducted air handler recessed in the second floor hallway ceiling and add a short duct run to each bedroom. This would solve the open/closed door problem and provide space conditioning to heat the bedroom.

Drawbacks of on/off operation. Deep temperature setbacks can exacerbate uneven temperature problems. After one homeowner complained of temperature unevenness, it was learned that they operated their MSHP in an “on/off” manner rather than using a fixed set point. This resulted in wide temperature swings between 60°F and 70°F+. The electricity use showed many hours with the MSHP running at maximum capacity, followed by periods with the unit shut off. This is the least efficient heating mode for MSHPs.

References: <http://1.usa.gov/1CWXd6>



Big Swings. Operating a MSHP in “on/off” mode resulted in wide temperature swings. Not surprisingly, electricity consumption for this house was a high consumption outlier.

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Optimal Whole-House Ventilation

Choosing the optimal whole-house ventilation system for an existing home can improve indoor air quality and prolong the building’s life.

INCLUDING A MECHANICAL system for removing contaminants is critical for ensuring indoor environmental quality in today’s tighter homes. A report from the Consortium for Advanced Residential Buildings (CARB) offers guidelines for selecting and installing ventilation systems for existing homes. (Note: Although the CARB report covers spot ventilation for bathrooms and kitchens, we are only including whole-house ventilation strategies.)

CHOOSING A SYSTEM

Before deciding on a ventilation strategy, the minimum flow rate must be determined. ASHRAE 62.2 has become the standard guideline for both local and whole-house ventilation. The latest (2013) iteration of the standard does away with the built-in “infiltration credit” and uses the following formula for calculating whole-building flow rate:

$$Q_{tot} = 0.03(A_{floor}) + 7.5(N_{br} + 1) (2)$$

Q_{tot} = Total required whole-building ventilation rate [CFM]

A_{floor} = Floor area [ft²]

N_{br} = Number of bedrooms

Note: If a blower door test is done, the ventilation flow rate can be reduced.

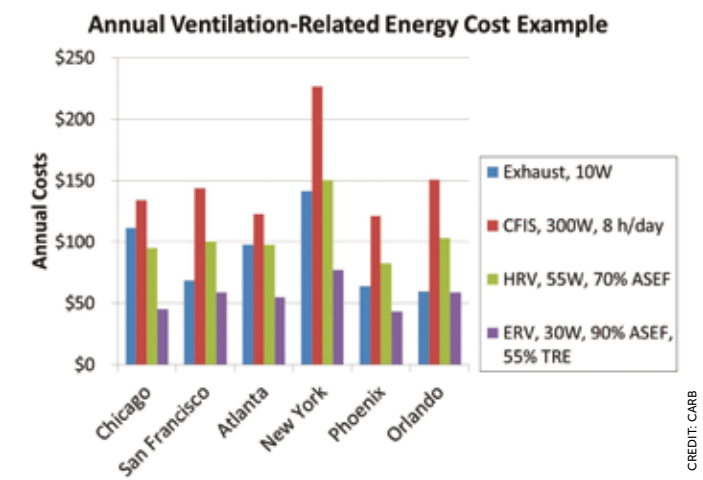
There are three main strategies to achieve whole-house ventilation: exhaust-only systems, central fan-integrated supply and heat or energy recovery ventilation. The choice of system depends on several factors, including existing HVAC system, existing ventilation, ease of accessibility and scope of the larger remodeling project.

EXHAUST-ONLY OPTIONS

In these systems, exhaust fans operate continuously (or on timers) to remove air from the home. Fresh air is introduced through induced infiltration. These systems usually make use of an exhaust fan that provides local ventilation as well, most often in a bathroom.

Pros

- Simple and affordable. Nearly all homes have exhaust fans, and upgrading one or more to efficient models designed for continuous operation is very straightforward.



Operational Costs. In general, ERVs are the most expensive ventilation systems to install but the least expensive to operate.

- Units that use very little electricity are available (5–12 watts for 50–80 CFM).
- Low maintenance, other than vacuuming or wiping the fan grille.

Cons

- Depressurizing the home draws in air from outside the home. Exhaust-only ventilation should not be used in homes with atmospheric combustion appliances, homes where makeup air comes from damp, moldy crawlspaces or basements or homes with attached garages that are not well air-sealed from the home.
- Ventilation is typically not distributed. A single exhaust fan removes air from one location, and makeup air enters where it will. Different parts of the home are likely to be ventilated to different degrees—especially when interior doors are closed.

Cost. Efficient exhaust fans range from \$100 to \$250, depending on rated flow rates, special features, etc. If installed as an upgrade (e.g., in a bathroom that already has an old exhaust fan, power and ducting), installation costs could be as low as \$100. If installed in a location which did not previously have a fan, costs can be much higher. If installed in a ceiling beneath an accessible attic, installation can be \$200-\$400. If drywall or finishes must be removed and repaired, costs can be substantially higher.

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CREDIT: CARB

Energy implications. A 10-watt fan running year-round consumes 88 kWh. At \$0.11/kWh, this costs \$10/yr. As this system doesn't include heat recovery, outdoor air brought into the building must be conditioned. These costs vary with climate and HVAC equipment, but they are usually much greater than the cost of electricity to operate the fan.

Location. Usually a single unit utilizing an existing duct run is adequate. In larger homes, it's better to install two fans, rather than a single fan with a higher CFM rating.

Equipment. Newer, ENERGY STAR-certified fans are more efficient and quieter. The CARB report recommends choosing a fan with 6 to 9 CFM/watt, which far exceeds the ENERGY STAR minimum standard of 1.4 CFM/watt.

Controls. Various strategies are available to achieve the desirable CFM, including continuous operation, adjustable speeds, programmable controls and on-demand controls.

CENTRAL FAN INTEGRATED SUPPLY

CFIS systems make use of an existing forced-air heating or cooling system. A duct is run between the return plenum and outdoors, and CFIS controllers are programmed to turn on the air handler fan and open the motorized damper. Outdoor air is drawn into the return plenum, mixed with return air and distributed throughout the home.

Pros

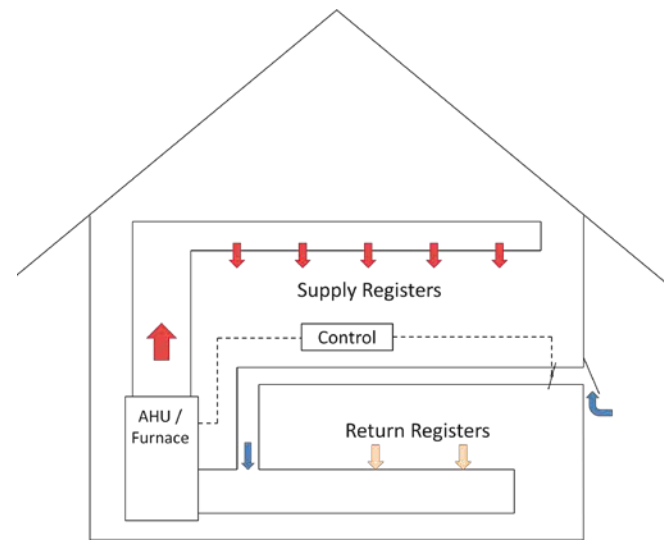
- Simple and affordable.
- CFIS systems distribute outdoor air to all parts of the home.
- Aside from keeping the air intake free from debris, a CFIS system requires little maintenance beyond maintenance of the central heating and cooling system.
- Outdoor air is filtered (through the central air handler filter).

Cons

- System is viable only in homes with forced-air heating or cooling systems.
- High electricity consumption from using the air handler fan for modest ventilation needs. This strategy should be considered only when the air handler has an electronically commutated motor (ECM) blower.
- Leaky central duct systems can drive up operating costs.
- Potential comfort problems if cool mixed air blows on occupants during the winter (or warm, humid air blows on them during the summer).

Cost. If the air handler is accessible in a basement or attic—and a duct can be fairly easily run from outdoors—total CFIS cost may range from \$500 to \$900; these costs include controls, motorized damper and installation. Installing the outdoor air duct and/or removing and refinishing drywall can bump the costs up significantly.

Energy implications. CFIS systems can consume tremendous amounts of electricity. Systems that utilize an efficient air handler fan motor (300 watts) and run an average of 8 hrs/day for ventilation (in addition to operation needed



Equal Distribution. CFIS systems take advantage of an existing HVAC system to distribute fresh air throughout the home.

for space conditioning) will consume 876 kWh/yr—an extra \$96, assuming a rate of \$0.11/kWh. Most central air handlers have motors that are not this efficient; it is not uncommon for draws to be two or three times higher. Basic CFIS systems don't include heat recovery, so outdoor air brought into the building must be conditioned. If the duct system is leaky, these costs can be even higher.

Considerations

Intake location. The intake should not be located in an attic, garage, basement or crawlspace. It should be located near the return plenum.

Ducting. Duct runs should be short and straight.

Fan motor. Installing a CFIS system with a PSC fan motor is not recommended, as energy consumption will be high. Fan motor replacements are available for some older furnaces.

Outdoor flow rate. In general, more outdoor air reduces the amount of time that the air handler must operate. But cool air can compromise comfort, and some manufacturers caution that the temperature of the mixed air passing over the heat exchanger should stay above a minimum temperature and/or that the outdoor air should not exceed 15 percent of the total flow rate.

Equipment. Kits often include a controller, a motorized damper and a transformer, though these components can also be bought separately.

Installation. Ducts should be sealed, and in cold climates, insulated.

HRVS AND ERVS

Heat recovery and energy recovery ventilators are balanced systems; they exhaust air and supply outdoor air simultaneously. These two airstreams cross in a heat exchanger, so during the winter, much of the heat in the exhaust stream is transferred

CREDIT: CARB

to the supply stream. In the summer, the reverse is true. HRVs transfer sensible heat only; ERVs also transfer moisture.

Pros

- Heat recovery reduces conditioning loads. The level of heat recovery (efficiency or effectiveness) varies among manufacturers.
- ERVs/HRVs can potentially distribute air to many areas in a home.
- These systems don't induce a large pressure (either positive or negative) on the building.
- Outdoor air can be filtered.

Cons

- ERVs and HRVs are typically more expensive and require more involved installation procedures.
- Higher maintenance, as filters and heat exchange media typically need to be cleaned or replaced regularly.
- Some systems have high electricity consumption.

Cost. The cost of ERV and HRV equipment ranges widely. Costs are generally proportional to heat transfer effectiveness and electrical efficiency. Until recently, costs for core hardware ranged from approximately \$400 to \$2,000. Recently, some higher end European products have become available in the U.S. market. These boast even lower electrical consumption (near 3 CFM/watt) and higher heat recovery effectiveness but with higher price tags of \$3,000 to \$5,000. Installation costs vary tremendously, depending on several key factors:

- Location of the core unit. If installed in an accessible space (such as a basement), core equipment and duct connections may be fairly simple.
- If ducts can be run in an open space (basement or attic), wall and ceiling finishes may be left mostly undisturbed.
- More and longer duct runs translate into higher installation costs.
- Need for a condensate drain and/or pump. Some contractors have found installation costs of \$1,000 to \$1,500 when the system is entirely installed in a basement, attic or other accessible space,

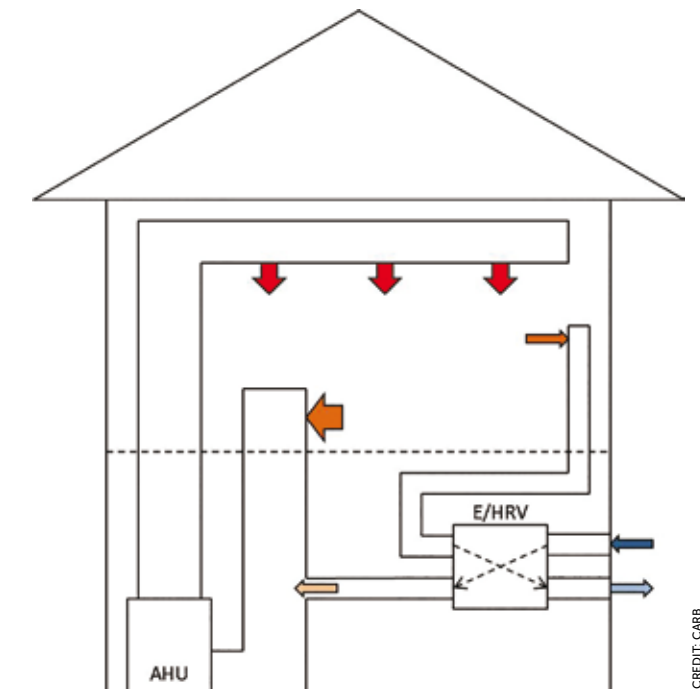
HRV or ERV?

Are typical indoor moisture levels more comfortable than outdoor levels? If yes, than an ERV is more practical. For hot, humid climates, an ERV is the better choice. For other climate zones, other variables come into play:

Colder climates, leaky homes: Indoor air is dry, so ERVs can help retain moisture within the home, improve comfort and possibly eliminate the need for humidifiers.

Cold climates, airtight homes: Indoor air humidity can be uncomfortably high, so HRV will help reduce indoor humidity.

Hot, dry climates, larger or leakier homes with low moisture generation may benefit from ERVs (to retain indoor moisture), while smaller, tighter homes with higher occupancy may benefit from HRVs (to reduce indoor humidity levels).



Ducts in a Row. At least one side of an ERV or HRV system should be ducted separately.

since very little ceiling or wall removal or finish work is needed. More complex installations will drive up costs substantially.

Energy implications. One of the main benefits of ERVs/HRVs is heat recovery. In colder climates, the savings from heat recovery are more pronounced. The electrical power consumption of these systems can also vary significantly; in milder climates, the electricity costs can actually be greater than the thermal energy savings.

Considerations

Ducting. Duct runs should be short and straight, and the unit should be accessible. Ducts should be sized for the higher flow rates.

Intake and exhaust. Outdoor air should be clean; it should not come from an attic, garage, basement or crawlspace. Baths should have separate exhaust fans to keep those areas from retaining moisture.

Central duct systems. Integrating ERVs or HRVs with central duct systems is not recommended. Outdoor air will follow the path of least resistance and exit through the return plenum, resulting in higher energy consumption and/or inadequate fresh air.

Equipment. Choose equipment with at least 80 percent ASEF value and a TRE greater than 50 percent. Quieter, more efficient units are typically more expensive. For cold climates, make sure equipment includes frost protection and condensate drains.

Installation. Ducts should be sealed and insulated.

References: <http://1.usa.gov/1PfOuJa>

CREDIT: CARB

Assembly-Line Attics

The Advanced Residential Integrated Energy Solutions (ARIES) research team has developed a low-cost and easily replicable approach for increasing attic insulation in factory-built homes.

INCREASING ATTIC INSULATION in manufactured housing has been a significant challenge due to cost, production and transportation constraints. The U.S. Department of Energy's ARIES research team, led by The Levy Partnership Inc., partnered with Clayton Homes's Southern Energy Homes division and Johns Manville Corporation to develop and test a new attic insulation method that involves dense-packing the shallow attic space in manufactured homes with blown fiberglass insulation before filling the rest of the space with loose fill. With this new method, installers are able to achieve a much higher attic insulation R-value than is typically installed in manufactured homes. The simplicity of this solution bodes well for widespread industry adoption.

THE METHOD

To dense-pack the attics, workers at the manufactured home plant use a "mold" consisting of a 24" x 48" sheet of pegboard, with a flange at one end and a hole in the center to receive the insulation tube. The mold is sized to span one rafter bay. The installers start at one end of the house and work their way down, filling each rafter bay from the eave out to the flange.

Once compacted, the fiberglass fibers tend to stay together, so filled bays can be left exposed as the installer moves down the bays. After dense-packing all the eaves, the remainder of the attic is filled with loose blown fiberglass to the desired depth. Baffles are then installed above the insulation to provide a clear path for air to flow from the soffit vents to the roof vents. The house then moves to the next station in the assembly line, where sheathing and roofing are installed.

This hybrid method achieves an average R-value of 44.6, compared to R-33 if it were only to contain loose fill. The method was tested in a home built by Southern Energy Homes to the performance criteria of the DOE's Zero Energy Ready Home program, which seeks to achieve whole-house energy performance that exceeds the requirements of the 2012 International Energy Conservation Code.

A SCALABLE STRATEGY

R-Value	Overall	Center of Peak
Southern Energy Homes Dense-Packing Method	R-44.6	R-54.6
ENERGY STAR-Qualified Manufactured Home Program	R-30 – R-38	N/A
HUD Code Zone 1 (Typical)	N/A	R-22

For the manufacturers, the beauty of this low-tech, low-cost technique is its simplicity and adaptability to current plant production processes. Immediately applicable to the nearly 125,000 new manufactured homes built each year, the technique addresses many industry barriers:

First cost. Affordability is an industry-defining characteristic. Even significant energy efficiency improvements that could increase the home's long-term affordability are shunned if they will increase initial home price. The dense-pack technique uses an insulation product that the builders felt provides the highest thermal benefit at the lowest cost. The insulation blower is



Easy as 1-2-3

Step 1: An employee at Clayton Homes's Southern Energy Homes plant uses a perforated hardboard "mold" to dense pack blown fiberglass insulation into the eaves of a manufactured home. The light-weight mold is 4 feet long and just wide enough to span the rafter bay. A flange at the far end holds the insulation in place as it is blown in.

Step 2: Installers start at one end of the house and work their way down, filling one bay at a time in about 23 seconds per bay.

Step 3: After all of the eaves are dense-packed, the remainder of the attic is filled with loose fill to the desired height.



Side by Side. The dense-pack roof insulation technique is being tested in a side-by-side comparison with two other manufactured homes—one built to ENERGY STAR standards; the other built to the HUD code.

already in use at most factories, and the cost of the hardboard is negligible. The small cost associated with the dense-packing measure is recovered immediately in reduced overall home operating costs, and the materials have a simple payback of less than three years.

Dimensional limitations. Because manufactured homes are transported over roads, they are subject to strict height restrictions. For example, in California the maximum height allowed is 14 feet, including the wheels, undercarriage, walls and roof. Consequently, attics are low, ranging from 2 to 3.5 feet at the peak and tapering to a heel height of 2.5 to 7.5 inches above the top plates. This leaves very little room for insulation. The dense-pack technique conforms to the constrained space and encourages consistent coverage in every rafter bay.

Production speed. Manufacturers avoid using new products or building methods if they are likely to slow the pace of production, require staff training to build it right and/or are susceptible to defects and recalls. The dense-pack technique uses insulation materials manufacturers are already familiar with in a way that minimizes impact on product flow. The method is simple and easy to learn, and it is easy to verify quality—major advantages in a high-paced production setting. Adoption could be implemented immediately on a large scale across companies without the need for retooling or other process changes.

A First in Zero-Energy-Ready Homebuilding

Clayton Homes's Southern Energy Homes subsidiary completed the first DOE-certified Zero Energy Ready manufactured home in Russellville, Alabama, last year. In addition to meeting all of the requirements that site-built homes must meet to qualify for the high-performance home labeling program, it meets the standards of ENERGY STAR 3.0 and incorporates the indoor air quality and water-saving measures of the U.S. EPA's Indoor airPLUS and WaterSense programs.

The home was built with wood-framed walls (2 x 4 studs spaced 16 inches on center) and some advanced framing techniques; for example, there are no extra studs at the doors and windows. To cut heat loss, caulk was applied around every plumbing, wiring, ducting and vent stack hole in the floors and ceilings. In addition to installing R-13 of unfaced fiberglass batt insulation in the wall cavities, the exterior of the walls was covered with a 1-inch layer of XPS rigid foam insulation sheathing, which was fastened to the studs with adhesive. The insulation values are R-54.6 in the ceilings, R-13 + R-5 in the walls and R-28 in the floors, well above 2012 IECC requirements for its climate zone.

The home also uses a new HVAC design that keeps the HVAC equipment completely within the home's conditioned



space. It is equipped with a super high-efficiency, mini-split heat pump with a SEER of 22 and a heating season performance factor (HSPF) of 12.

Duct-Sealing Strategies for Retrofits

A side-by-side field study of two duct-sealing techniques shows that both methods are effective and save energy with relatively short payback times.

DUCT SEALING CAN BE DIFFICULT, costly and disruptive to deal with in a retrofit situation. The Advanced Residential Integrated Energy Solutions (ARIES) Collaborative conducted a field study to compare two techniques: manually applied sealants and injected *Aeroseal* aerosol. Their goals were to understand and compare the cost and effectiveness of these two approaches and to identify the logistical and technical issues that might affect large-scale implementation in low-rise multi-unit residential public housing complexes.

SIDE-BY-SIDE TESTING

This study took place in 40 units in two housing developments in North Carolina. The developments included one- and two-story units that utilized central air conditioning and natural gas heating. The ductwork included both flex ducts and metal ducts, attic and floor ducts, and ducts inside and outside of conditioned space. The air handlers were all located in conditioned space.



By Hand. Mastic was used to hand seal air handlers from the outside.

Half of the units were treated with hand sealing, while the other half were treated with injected *Aeroseal* aerosol sealant.

Scope of Hand Sealing:

- Register boots were sealed to the floor or to the ceiling.
- Return plenums were sealed inside with mastic.
- Air handlers were sealed from the outside with mastic.
- Where accessible, the ridges trunk ducts and the trunk to flex duct connections inside attics were sealed with mastic.

Scope of Aeroseal Sealing

Aeroseal sealant could reach ducts that were inaccessible by hand. Return ducts were too small to use the *Aeroseal* system, so these were hand sealed. Air handlers and junctions between registers and walls, ceilings and floors were also hand sealed. (Note: In many cases the *Aeroseal* can be used to seal return systems. A wide connector in the duct system can split the air stream towards the return and the supply so both are treated at once.)

RESULTS

On average, hand sealing resulted in an almost 60 percent reduction in duct leakage to the outside, whereas the *Aeroseal* system showed a 91 percent reduction—a 32 percent improvement over hand sealing alone.

Return and supply flows, as measured by a fan-powered flow meter, increased after both treatments. Return flow increased by an average of 7 percent, but increases were higher with the *Aeroseal* system. One unit showed decreased flow afterwards; this was likely due to damage or compression of a duct in the attic.

While *Aeroseal* does seal ducts to a much tighter level than hand sealing, about 70 percent of the leakage reduction in the *Aeroseal* units was due to hand sealing at the returns, registers and other locations.

Energy savings and cost. Whole-house source energy savings ranged from 3 to 7 percent for the various units. The cost for hand sealing ranged from \$275 to \$511 per unit. The cost was higher for single-story units because workers had to climb into the attics to address the leakage, whereas the ducts in the two-story units were located in between floors and so were inaccessible. The sealing in those units was confined to the registers and air handler and at the return. The *Aeroseal* treatment cost a flat rate of \$700 per unit.

Return on investment. An analysis of utility bills from one year before and one year after the retrofits shows that on average, the units enjoyed a 15 percent reduction in heating and cooling energy use. Hand sealing resulted in a shorter



Precise Control. A computer monitors the flow rate, temperature and humidity levels of the air stream, indicating adjustments that need to occur so that the *Aeroseal* sealant is neither too dry nor too wet when delivered.

The Aeroseal Process

Aeroseal, created from work done at Lawrence Berkeley National Laboratory in 1994, seals ducts from the inside of ductwork. The *Aeroseal* sealant particles are partially dried before they enter the duct system, so they will not stick to the duct walls. The sealant consists of a vinyl material suspended in a water solution. The *Aeroseal* process puts escaping air under pressure and causes polymer particles to stick first to the edges of a leak, then to each other until the leak is closed.

The set-up is straightforward but somewhat time consuming. Supply registers are sealed with compressible foam plugs to contain the sealant inside the duct and prevent it from dispersing into the building. The sides of the coil and other HVAC equipment are sealed off to protect from sealant material. *Aeroseal* equipment is attached together using a plastic tunnel, or duct. This is used to give the sealant time enough to dry before entering the ducts. A computer controls and monitors the process.



Space Challenged. The plastic tunnel required to inject the *Aeroseal* sealant into the duct system can be awkward to set up in small spaces.

simple payback: just over two years versus 4.7 years for the *Aeroseal* treatment.

LESSONS LEARNED

Both the *Aeroseal* method and manual sealing stop leakage. Because the *Aeroseal* method is less familiar, the researchers noted several advantages, challenges and recommendations for

Method	Energy Savings (therms)	Energy Savings (kWh)	Utility Bill Savings/Unit	Simple Payback (years)	Sample Size
Hand sealing	30	809	\$179	2.2	7, 1-story 4, 2-story
<i>Aeroseal</i> ®	19	731	\$150	4.7	5, 1-story 2, 2-story

readying the system for production-scale use.

Advantages. This system allows sealing of inaccessible ducts. It also avoids some of the hassles of manual sealing, which involves removing duct insulation, cleaning ducts, applying masking, waiting for it to dry, reapplying insulation, kicking ducts loose and other quality control issues.

Challenges. Small units made set-up challenging. The humid environment created some difficulties in keeping globules of sealant dry on the outside, which caused some clogging issues.

Recommendations. Because the set-up and clean-up are so involved, most of the time the *Aeroseal* equipment was not actually actively sealing ducts. Using a Y connector to serve multiple units at once would save time. The researchers also recommend using a scaled-down system for small units.

Presenters: Jordan Dentz, Advanced Residential Integrated Energy Solutions (ARIES), and Francis Conlin, High Performance Building Solutions, Inc.

References: <http://1.usa.gov/1SOTOFx>

Combined Water and Space Heating

Single-source water and space heating, or “combi” systems that optimize efficiency are being developed through a series of lab tests and field trials.

BETTER INSULATION AND tighter envelopes are reducing space heating loads for new and existing homes. This makes it possible for both space and domestic water heating loads to be provided with a single heating plant, saving significant amounts of energy. These systems are called combination (combi) systems and have been the focus of ongoing field and lab studies conducted by the NorthernSTAR Building America Partnership.

HOW THEY WORK

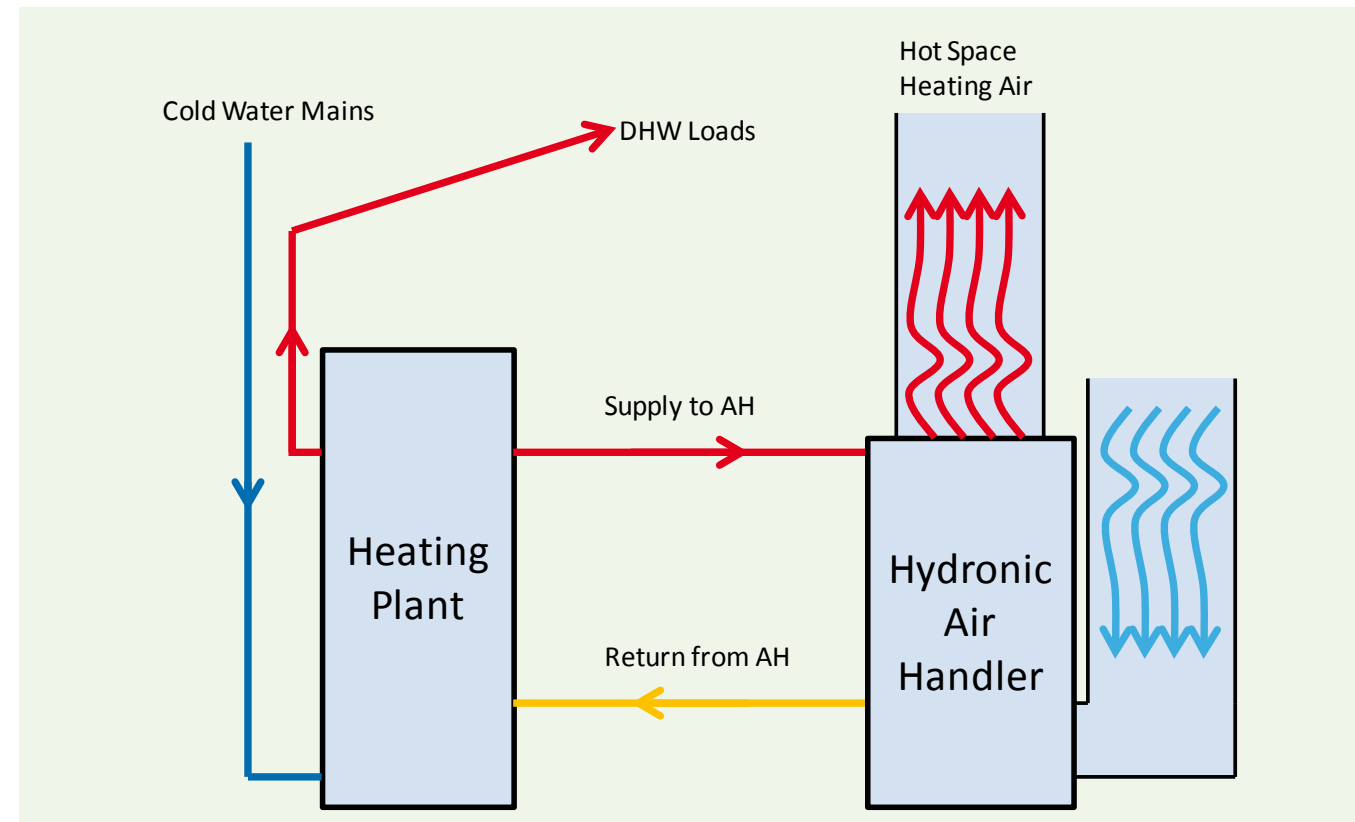
Combi systems can directly replace the existing forced-air furnace and water heater. They consist of a high-efficiency water heater or boiler and an optimized hydronic air handler. The air handlers are designed with large heat transfer coils to achieve highly efficient space heating.

During a space heating event, hot water leaves the heating plant, passes through the coil in the air handler and transfers heat into the airflow. The cooler water then leaves the air handler and flows back to the heating plant. Closed loop systems use a heat exchanger between the heating loop in the heating plant and the air handler.

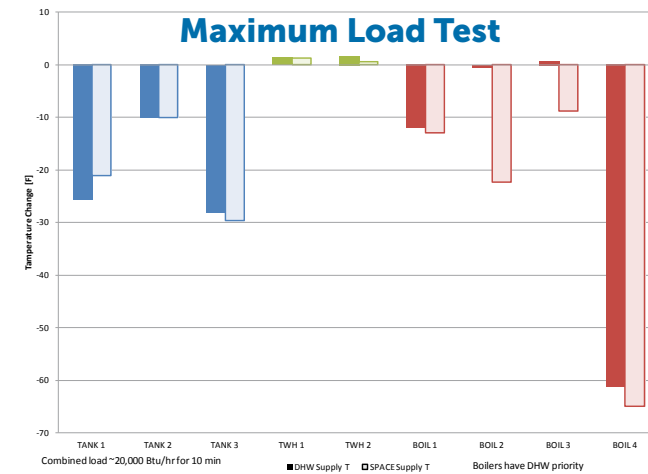
In addition to saving energy, these systems virtually eliminate natural draft appliance spillage issues through the use of a powered or direct combustion vent.

IN THE LAB

The NorthernSTAR team created a testing laboratory to design and optimize combi systems ahead of a field trial in which such



A Typical Open-Loop Combi System. During a hot water draw, the heating plant operates like a water heater: cold water comes into the storage volume as hot water leaves (for units with storage). In systems without storage, cold water enters and is heated as necessary.



Full System Performance. The graph shows the change in supply temperatures from start to finish of a “maximum load” test, which consisted of two showers and one space heating event. The tankless water heaters maintained the most consistent temperatures.

systems would be retrofitted in 300 homes participating in the State of Minnesota Low-Income Weatherization Assistance Program.

The lab phase documented the performance of currently available components and developed recommendations for optimized combi system designs. Tests were conducted on individual components, including nine heating plants and nine hydronic air handlers. Steady-state measurements of the air handlers determined output capacities that provided acceptable return water and supply air temperatures. Heating plant capacity results were used to develop algorithms to determine whether a system could meet domestic hot water (DHW) and space heating loads. Finally, multiple systems were configured and tested. Experienced contractors reviewed initial designs to provide recommendations to improve performance, reliability, ease of installation and cost.

CONCLUSIONS

High return water temps compromise efficiency. Lab tests showed that the heating plant steady-state efficiency decreased with increasing return water temperature; this decrease became more significant as the return temperature increased above 110°F. Optimal systems require water and air flow rates that result in low return water temperatures while still meeting loads.

Today’s combi technology can do the job. Tests verified that systems are capable of meeting heating loads up to 50,000 BTU/h with acceptable return water temperatures and supply air temperatures. These designs provide steady-state space heating efficiencies >85 percent.

The performance of combi systems is limited by currently available equipment. Most hydronic air handlers were not designed to produce the lower return water temperatures necessary for combi systems with a condensing heating plant. Also, the manufacturer requirement that plumbing

continued on page 26

Testing, Testing

The NorthernSTAR combi lab evaluated nine heating plants individually using three different tests:

1. Idle tests. These were conducted by recording gas and electricity consumption when the heating plant had no DHW use or space heating load. Infrared thermography was used to help identify sections of the heating plant with significant heat loss.

2. Steady-state space heating efficiency. These tests were conducted using a “work horse” heating plant that supplied hot water at a set flow rate and temperature, simulating the water conditions returning from a hydronic air handler. Efficiencies were computed by measuring the energy into the heating plant, in natural gas and electricity, and the energy output in hot water. Return water temperatures (ranging from 80°F to 120°F) were monitored in order to track the efficiency reduction with higher return temperatures. This helped determine an optimized flow rate and heat output sizing of the hydronic air handler.

3. Transient performance. Conducted to examine delivery capabilities, these tests tracked water temperatures during a sudden increase in DHW flow in order to determine hot water delivery times. The tests also tracked transient supply water temperature under three simulated conditions: (1) a space heating event interrupted by a DHW event (e.g., a shower); (2) a shower interrupted by a second shower; and (3) a shower interrupted by a space heating event.



Current Technology. The nine heating plants tested included four condensing combi boilers with heating loops for space and domestic water heating, two with internal storage for hot water, three condensing storage tank type water heaters, one condensing tankless water heater and one condensing hybrid water heater.

for combi systems be configured with a primary and secondary loop significantly increases return water temperatures, thus reducing system efficiency. Variable flow rate water pumps and fans, along with the necessary controls, could provide a greater range in heating output while ensuring low return water temperatures. Such modifications could improve system efficiency as much as 10 percent. Several manufacturers, at least one in direct reaction to the findings from this project, have begun to improve combi equipment.

RETROFITTING COMBI SYSTEMS IN THE FIELD

As a next step, the NorthernSTAR team monitored 20 homes to characterize how combi systems performed compared to existing systems. At each of the homes, the team installed a detailed monitoring system that collected data on energy use, household load and system efficiency. After a full year of monitoring, the team found that the combi systems saved 19 percent of natural gas usage for space and water heating and showed an annual average combined efficiency of 87 percent.

The combi systems were shown to have the same gas consumption as separate high-efficiency natural gas furnaces and water heaters, at lower first costs. However, combi systems are tricky to install, and many installers are unfamiliar with them. This makes it difficult for combi systems to economically compete with a common installation of a condensing furnace and power vent water heater.

LESSONS LEARNED

- The water temperature returning to the heating plant must be minimized to achieve condensation. Water temperature of 105° F or lower was targeted to ensure high performance.
- Custom design, equipment pairing and optimization were required to balance high performance with occupant comfort at each site.
- In addition to energy savings, these systems improved the combustion safety of homes. In some cases, the flexible capacity of the combi system improved sizing and led to a more comfortable conditioned space for occupants.
- Separate condensing space and water heating equipment can be installed to reach comparable energy performance and combustion safety as combi systems, but separate systems are more expensive.

ADVANCED CONTROLS

One of the takeaways from previous work was the need for advanced controls to further enhance the efficiency of combi systems.



Tweaking the System. The energy efficiency of combi systems depends largely on (1) the water temperature returning to the heating plant from the air handler and (2) burner cycling characteristics.



Upgrade. The retrofitted combi systems typically operated in the condensing mode and provided acceptable, and in some cases, improved occupant comfort.

The NorthernSTAR team analyzed two distinct temperature set point controls: (1) outdoor reset and/or turndown after the heating season and (2) space-heating modulation (water flow and airflow). Each increases system efficiency, improves occupant comfort, saves energy and simplifies the sizing and design process.

Lower return temperatures and longer cycles produce higher system efficiency. Yet all air handlers have a constant airflow rate and constant water circulation flow rate for the heating mode. Advanced controls allow for a range of heating capacities for a single system; they improve efficiency by allowing the system to operate at lower average return water temperature and longer cycles.

Advanced controls can also reduce the need for custom engineering of combi systems. “Smart” control of airflow and water-flow rates could allow a single air handler to provide more efficient performance over a wider range of heating loads and should eliminate time-consuming manual adjustments to the airflow and water-flow rates. This way, the installer can focus on assembling functional systems, while the controller optimizes system operation.

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Are Mini-Splits Ready for Prime Time?

Mini-split heat pumps are gaining in popularity and could prove a valuable efficiency upgrade for multi-family retrofits.

MINI-SPLIT HEAT PUMPS (MSHPs) are a promising technology for both new construction, where multiple units can be strategically located, and for retrofit as a replacement of old, inefficient HVAC systems where space is often at a premium. In particular, they hold promise as a solution for replacing deteriorating or obsolete central heating systems in multi-family buildings, and for replacing electric resistance heating systems in cold climate buildings.

A report by the Advanced Residential Integrated Energy Solutions (ARIES) Collaborative investigates whether mini-splits can live up to their potential for the multi-family retrofit market. It includes models which analyze the cost effectiveness of MSHP retrofits compared to alternative retrofits or maintaining existing systems in a variety of climates. The report also compares the technology’s costs and benefits relative to alternatives and includes objective guidance on the best applications for MSHPs.

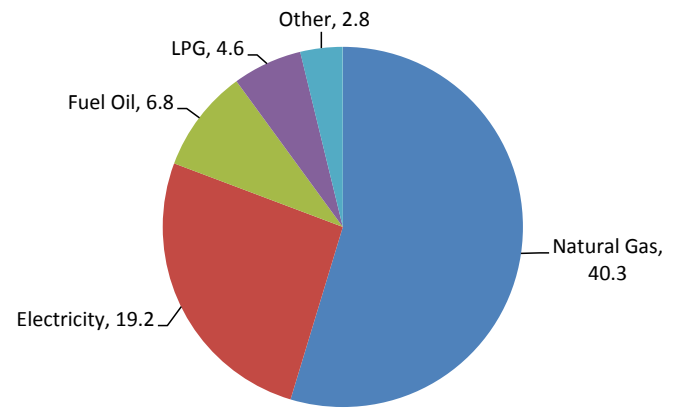
ENERGY COST MODELING

An analysis was performed to estimate the heating and cooling costs and energy use for a typical apartment in a multi-family building (hot water or steam heat), comparing MSHPs to a variety of other fuels. The annual cost to heat the apartment is lowest for natural gas, followed closely by the MSHP, with oil, LPG and electric resistance costing approximately two to

Heating Fuel	MSHP Savings (\$)	MSHP Savings (%)
#2 Heating Oil-Fired Boiler	\$424	39%
Natural Gas-Fired Boiler	\$25	4%
Electric Resistance Baseboard	\$1,003	60%
LPG-Fired Boiler	\$832	55%

Clear Winner. For the typical apartment, converting to MSHPs for space conditioning would reduce heating and cooling energy bills by more than half for all fuels except for natural gas.

Number of homes (in millions) by type of fuel used for primary space heating in cold, very cold and mixed-use climates.



Opportunity. Nearly half of the homes in these climates could save substantial amounts on heating bills by converting to high-efficiency MSHPs.

three times as much. When compared to room air conditioners, MSHPs reduced cooling cost by about 60 percent. (Note: the report acknowledges that because room ACs are noisy, they might be used less than MSHPs, and so the saving might not be as great.)

BEopt v2.0 was used to predict annualized energy-related costs and source energy consumption for a three-story, 11-unit building. Because BEopt is not intended to model entire multi-unit buildings, the 5,925-sq.-ft. building was modeled as a single large home. This was a reasonable assumption because the building has a single boiler and only space heating and envelope measures were varied in the analysis.

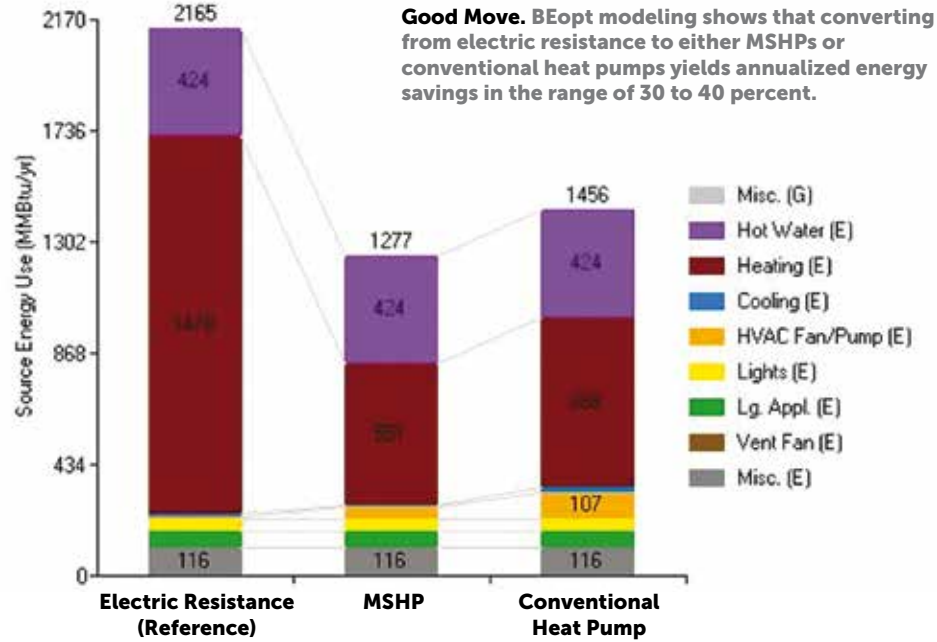
The models calculated annualized energy-related costs for three scenarios: converting to heat pumps from electric resistance, oil and natural gas, each in two climates of New York and Boston. (Note: BEopt includes fan/pump energy with heat pump equipment because it assumes a central system with forced air distribution. This energy would not be expended with point-source systems, so BEopt slightly overestimates the energy expense for these options.)

Converting from electric resistance to MSHPs. This shows annualized energy savings on the order of 30 percent. MSHPs provide 41 percent source energy savings, compared to 33 percent for conventional heat pumps. Both Boston and New York showed the same energy savings percentage.

Converting from oil to MSHPs. This conversion reduces *continued on page 28*

annualized energy expenses by about 2 to 6 percent. New York showed a greater percentage reduction in energy consumption than Boston in this case. Energy consumption was greater for conventional heat pumps than with oil for both cities.

Converting from natural gas to MSHPs. This was the least cost-effective conversion. New York saw an energy savings of 2 percent by converting to MSHPs, but Boston saw a net increase of 2 percent. Both climates saw an approximately 16 percent increase in energy consumption by switching to conventional heat pumps. (Note: the model assumes water heating by natural gas.)



RETROFIT EXAMPLES

Successful multi-family retrofits were identified in three states, although they were all retrofits of buildings with electric resistance heating, the lowest hanging fruit. Most of the units were one- or two-bedroom apartments in single-story or two-story buildings.

1. Efficiency Maine’s Low Income Multifamily Weatherization Program. Since 2012, approximately 600 MSHPs have been installed; many sites also included envelope improvements.

2. The Connecticut Energy Efficiency Fund Home Energy Solutions—Income-Eligible program. In 2011, 3,576 MSHP units were installed at 51 sites.

3. BCMW Community Services. This weatherization agency in Centralia, Illinois, installed MSHPs under a low-income multi-family weatherization project in a development known as the Library Apartments.

Controls. These programs yielded lessons about interfacing with tenants. The standard MSHP controls are far more complex than what residents were accustomed to with electric resistance heaters. The Maine program switched from the standard remote control to a simpler wall-mounted thermostat. Residents also found the user manual difficult to understand. Program administrators recommend a simple one-page “quick start” guide.

Technical barriers. Very few technical barriers exist to promoting MSHPs in multi-family retrofits. Buildings over nine stories must accommodate locations for outdoor compressor units, either on balconies, mounted on exterior walls, etc.

Utility billing. If the building previously had central heating, installing MSHPs may change how space heating is billed. If the building owner still wants to pay for central heating, creating separate circuits for MSHP evaporators is required.

Peak demand. Replacing electric resistance space heating with MSHPs can reduce peak demand during both the heating

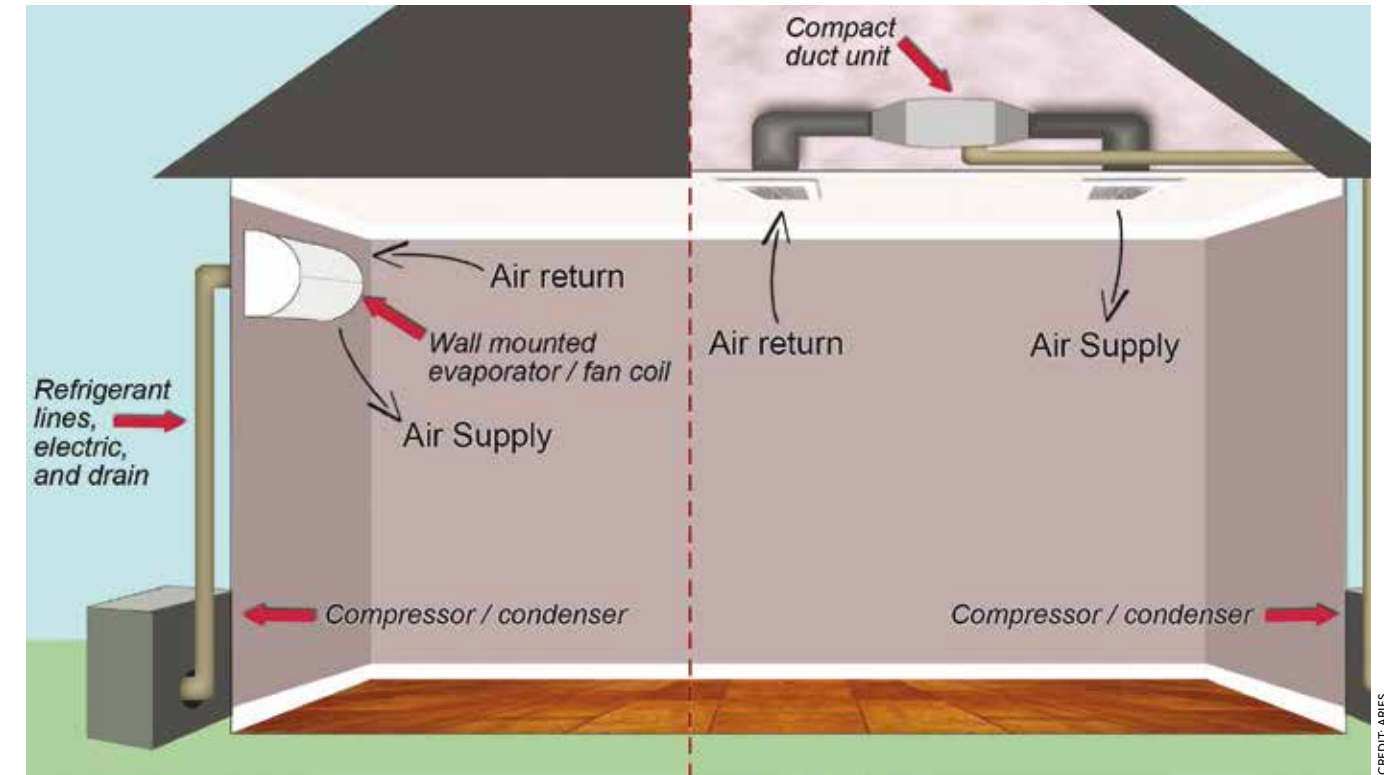
and cooling seasons by 40 to 60 percent. Converting from fossil fuel heating will increase winter peak demand.

Costs. A survey of New York contractors showed installed costs for multi-unit MSHP retrofits ranged from \$2,100 to \$2,577 (for a single-head, 9,000-BTU unit) to over \$5,000 for a three-head, 24,000-BTU system. The three retrofit programs reported the following costs:

Program	Equipment (Per Unit)	Installed Cost (Per Unit)
Maine	\$1,041	\$2,229
Connecticut	N/A	\$3,000 – \$4,000
Illinois	\$1,300 - \$1,500	N/A

Distribution. Ensuring adequate distribution of conditioned air from point-source MSHPs in retrofits is a balance between additional indoor units (at significant cost), envelope improvements and other means of air distribution. None of the multi-family retrofit projects investigated used distribution techniques other than door undercuts. With the exception of the studio apartments in the Connecticut program, all units had at least one bedroom without an MSHP evaporator, meaning these rooms relied on passive distribution.

Occupant comfort. Changing from central steam heating provides more thermal control (and comfort) to occupants, as central steam systems are prone to overheating apartments. Changing from electric resistance heating provides better mixing of air to distribute heat and potentially improves control via programming and setback opportunities, although MSHPs do introduce some fan noise. Changing from room air conditioners generally provides more cooling capacity at a lower cost, with lower fan noise, better mixing of air and humidity control. In addition, one compressor can be connected with multiple indoor units, and each indoor unit can be controlled separately.



Maintenance Strategy. Because the units are distributed throughout the building, maintaining them can require access to apartments, rooftop, balcony or exterior wall locations.

This provides true zoning and can optimize comfort by room, although efficiencies are typically lower for multi-head systems.

Occupant health and safety. The superior control of MSHPs will reduce overheating, which can create unhealthy, low-humidity environments. MSHPs also do not have potentially hazardous high-temperature components exposed in the living spaces.

System reliability. Independent, distributed heating equipment avoids situations where the entire building must be shut off for maintenance or repairs. However, tracking the long-term performance of MSHPs in cold climates is imperative.

Equipment durability. MSHPs are more sensitive to physical damage, require regular filter cleanings and include an outdoor compressor that is exposed to the elements and possible damage. This is an additional burden on building staff and a potential expense for owners. If the building owner is not receiving the benefit of energy savings, then he or she may be incurring additional unrecompensed costs for repairs. For public housing agencies that are reimbursed for utility bills by the state or federal government (or whose residents are), it may be hard to justify additional repair and maintenance expense.

Equipment maintenance. MSHPs require more maintenance compared to electric heating elements. They have many fragile parts, such as the fins on outdoor units, condensate pump and tubing. MSHP maintenance may require outside service personnel, whereas the radiators of steam and hydronic systems often can be serviced by building staff.



Climate Control. MSHP compressors must be protected from melting snow dripping from roofs above them.

References
<http://1.usa.gov/1ODWv90>

Rigid Insulation: Best Practices

Extra-thick layers of exterior insulation can greatly improve the energy performance of homes, but installation requires some special techniques.

INCORPORATING EXTERIOR INSULATION on wall assemblies addresses many common building enclosure energy and durability issues. Exterior insulation can increase the overall thermal resistance of the assembly; it also provides increased condensation resistance in cold climates.

Building Science Corporation has produced a Measure Guideline that covers the use of rigid exterior insulation boards such as expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate (PIC) and rigid mineral fiber (MF) as exterior insulation on wall assemblies. It also addresses the use of layers of insulation thicker than 1-1/2". These extra-thick layers exceed the practical limit of directly attaching siding through the insulation back to the structure, and so require a secondary cladding attachment location.

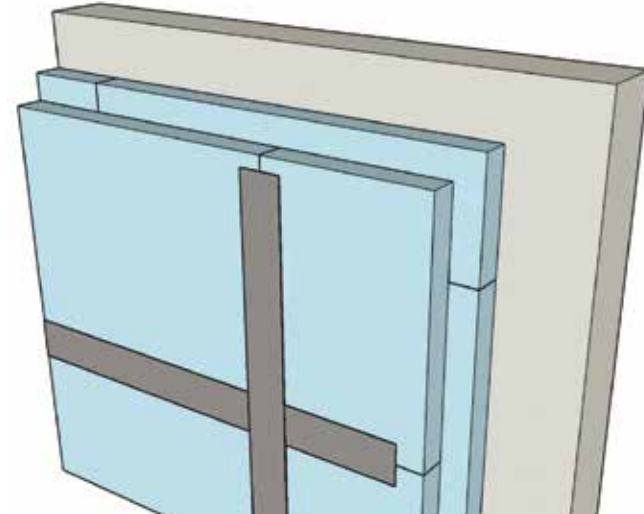
PLACEMENT OF CONTROL LAYERS

Wall assemblies include four "control layers" that protect the building and increase its energy performance and comfort: (1) water control layer; (2) air control layer; (3) vapor control layer; (4) thermal control layer.

Air control. This can occur from the inside of the building or at the sheathing; the rigid insulation can also serve as the air control layer.

Vapor control. When rigid insulation is added to the exterior of the structural sheathing, the interior surface temperature of the structural sheathing increases. When the temperature of the condensing surface of interest is raised sufficiently, interior water vapor migrating into the wall assembly does not condense. This allows assemblies to be constructed in cold climates without interior vapor control layers. The amount of exterior rigid insulation needed is a function of the climate and the amount of insulation added to the interior wall cavities.

Thermal control. Exterior rigid insulation can significantly improve the wall assembly's thermal performance because the continuous layer diminishes thermal bridges. The amount of exterior insulation added to the assembly will depend on the climate zone and design goals. Minimum levels should be based on the minimum requirements for vapor control and minimum building and energy code requirements. More insulation can be added to create high R-value wall assemblies; these typically add 4" or more of exterior rigid insulation.



Double Duty. When the joints of the exterior insulation are taped and sealed, it can act as the water control layer.

Water Control. The water control layer can be installed in front of or behind exterior rigid insulation. When it is located in front of the insulation, two approaches can be used:

- Install building paper or housewrap over the top of the rigid insulation. This option should only be used when the rigid insulation is 1-1/2" thick or less.
- Tape or seal the joints of the rigid insulation to act as the water control layer.

When the water control layer is located behind the rigid insulation, typical products include building paper and housewrap. Other options include fully adhered membranes, liquid-applied membranes and the taped-and-sealed joints of faced structural panels. These products should be installed according to industry standard practice and are independent of installing the rigid insulation. All flashing and other water control interfaces must connect to the wall water control layer.

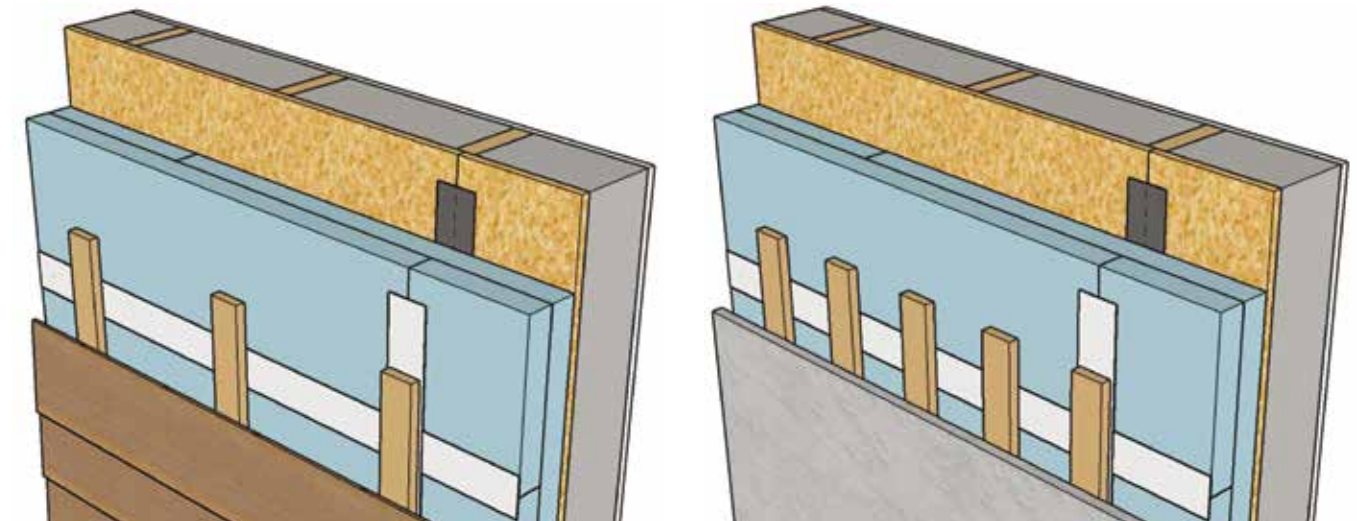
CLADDING CONSIDERATIONS

No fundamental changes are required to the building's structural design to accommodate exterior rigid insulation. It can be installed in either a single layer or in multiple layers, but the joints should be offset in multi-layer applications.

Mechanical and electrical penetrations should be sealed at the location of the water control layer. The sealing details are similar to those used with a sheet WRB, so the top edge of any membrane flashing should be adhered with construction tape.

For thinner insulation, the cladding can often be attached directly through the rigid insulation back to the structure. The practical limit of this approach is around 1-1/2" of rigid insulation, due to the limited fastener lengths for many pneumatic nail guns.

Extra-thick insulation. For thicker insulation, vertical wood furring strips can provide a cladding attachment location.



Siding Support. Furring strips support the cladding when extra-thick layers of exterior insulation are used. Stucco requires additional furring strips to facilitate installation.

This approach also provides a drainage and ventilation gap behind the cladding, which helps manage water. To adequately support the cladding, the furring strips should be attached back to the structure using #10 or larger wood screws that are sized to maintain a 1-1/4" minimum embedment into the structural

framing. For example, a 6" wood screw can be used to attach up to 4" of insulation (4" insulation + 3/4" of furring + 1-1/4" of embedment = 6" total).

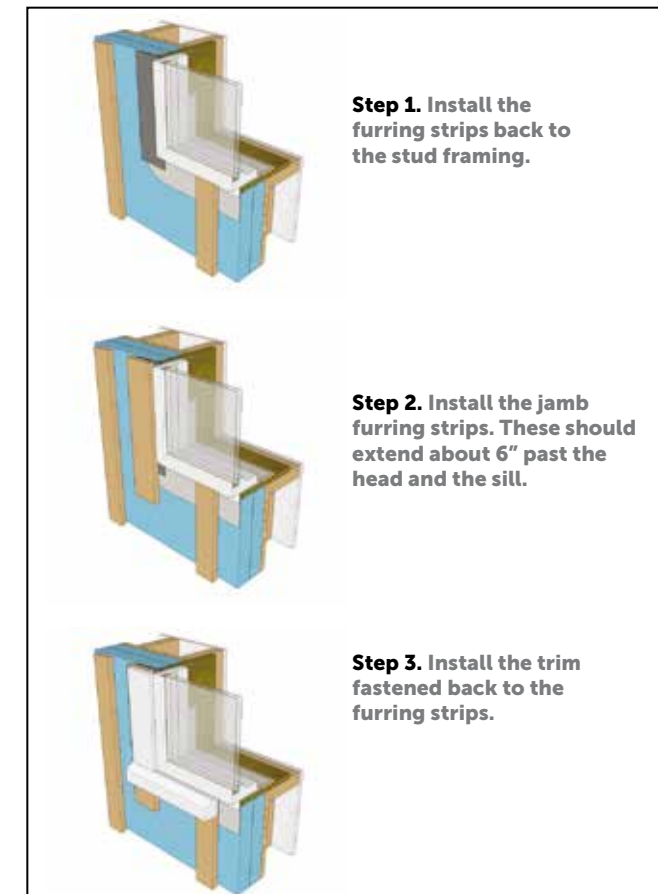
Stucco and stone veneer. Some claddings, such as stucco and adhered stone veneer, may require additional support between the structural furring strips to facilitate the installation. In these cases, additional structural furring or nonstructural spacer strips can be added.

Shingles. Wood shingles require a continuous nail base, which is best provided by installing another layer of structural sheathing directly over the insulation in place of wood furring strips. The new sheathing becomes analogous to the wood structural sheathing of the wall assembly, so water management details can now be managed exactly per standard construction.

Openings. At openings such as windows and doors, the details for trim attachment can differ slightly from standard construction practice. At the head and sill, the furring strips that are already in the field of the wall are generally sufficient to attach those elements; however, additional furring strips at the jambs are generally required to attach the jamb trim and support the abutting cladding.

If the sill profile is similar to a traditional sill, attaching it through the front face of the trim is often impractical. In this case, small segments of furring strips can be preattached to the back of the sill and the furring can be attached back to the structure to attach the trim. The head flashing above the head trim does not need to be installed all the way back to the water control layer. In reality, that flashing principally maintains the shingle lapping of the siding with the trim, and can thus be installed over the top of the furring.

Additional details, as well as instructions for integrating exterior rigid insulation with windows, roofs, balconies and decks are included in the Measure Guideline.



Adjustments. If using furring strips to provide cladding attachment, additional furring is needed to accommodate the jamb trim.

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<http://1.usa.gov/1lbBKhu>

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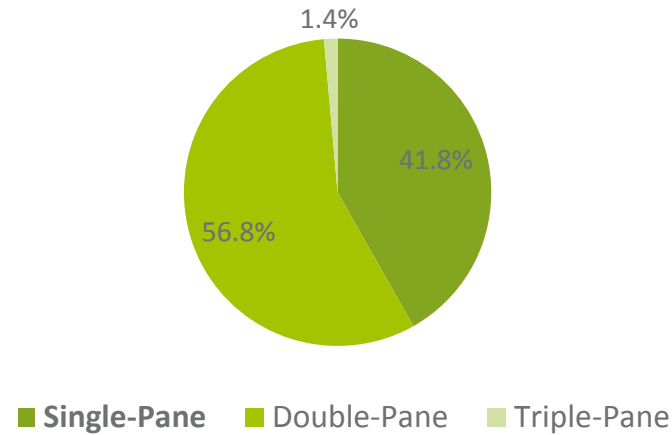
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Cost Analysis: Low-E Storm Windows

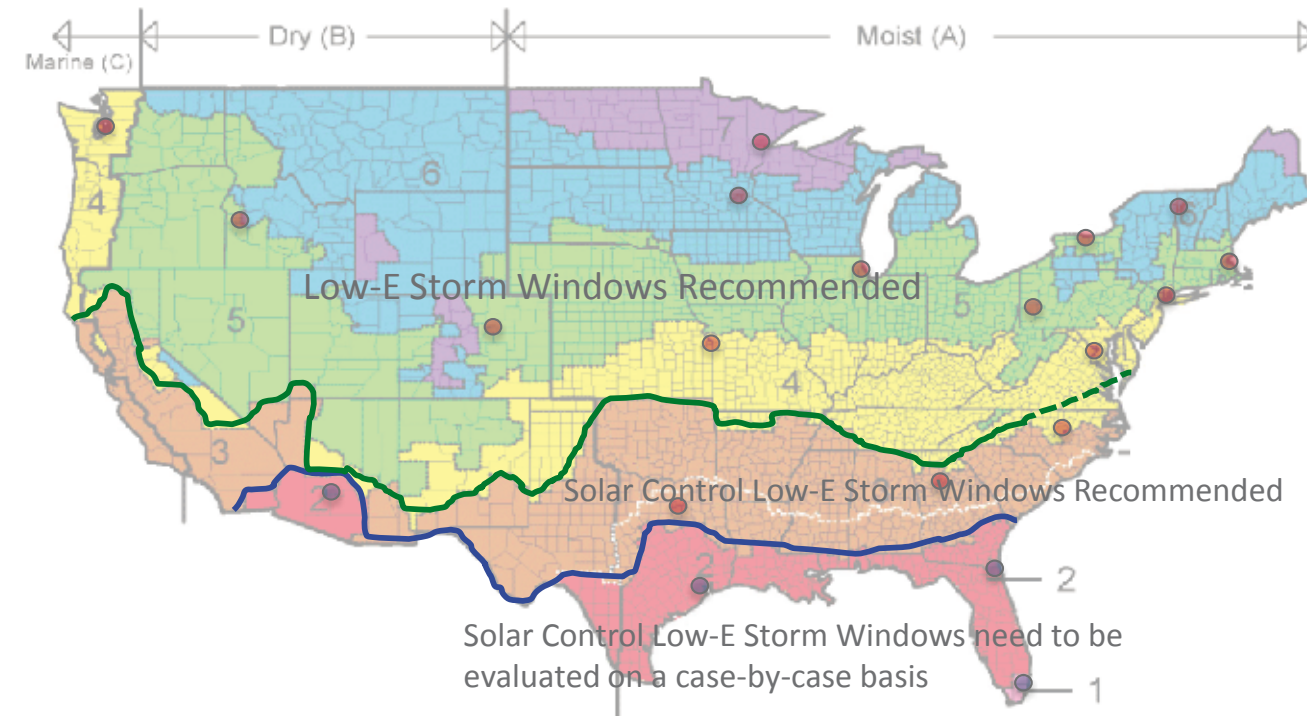
High-performance storm windows are a lower-cost alternative to window replacement and can save significant amounts of energy.

WINDOWS ARE A MAJOR SOURCE OF heating losses and gains in the building and can significantly drive up energy bills. Window replacement is not an option for many homeowners, whether the cost is too high or because they want to keep the historical integrity of their homes. Low-E storm windows can provide a cost-effective alternative to replacement; in particular, for moderate and low-income households. DOE has supported technology development, market assessment and early deployment of low-E storm windows through a variety of research, including climate-based modeling and field lab tests.

Percent of Homes in the US with Each Window Type



Window of Opportunity. Over 40 percent of existing homes have single-pane windows. In addition, almost half of all the double-pane windows are not high-performing low-E windows, but are made of clear glass.



Wide Application. Low-E storm windows and interior panels installed over all single-pane windows, as well as all double-pane metal frame windows with clear glass, are cost effective in climate zones 3 through 8. In climate zone 3, solar control low-E storm windows are recommended.

Three Ways Low-E Storms Improve Windows

1. They provide air sealing of the primary window, for up to 10 percent reduction in air leakage of the entire home.
2. A low-E storm window creates dead air space, which reduces conduction and convective heat losses across the primary window.
3. Low-E glass reflects radiant heat back into the home.

THE PNNL LAB HOMES TEST

Building on previous research, the Pacific Northwest National Laboratory (PNNL) recently tested low-E storms on manufactured homes to determine the energy savings and payback periods. Side-by-side tests were conducted in two Lab Homes built in Richland, Washington. These manufactured homes were provided by Marlette, a manufactured housing manufacturer in Hermiston, Oregon. They were specified so that they would be representative of 1970s-era housing stock in the Pacific Northwest region. For example, insulation levels for floors, walls and ceilings are R-22, R-11 and R-22, respectively. The windows are double-pane, clear glass with aluminum frames. The

	Baseline Windows Windows/Patios Doors	Low-E Storms over Baseline Windows	Highly Insulated Windows/ Patios Doors
U-factor	0.68 / 0.66	0.33 / 0.32	0.20 / 0.20
SHGC	0.70 / 0.66	0.53 / 0.50	0.19 / 0.19
Visual Transmittance (VT)	0.73 / 0.71	0.61 / 0.59	0.36 / 0.37

performance of these baseline windows was compared to the performance of those same windows with exterior low-E storm windows attached, and to highly insulated windows retrofitted into the lab home.

Performance measures. Windows with low-E storms showed significant reduction in the U-factor and solar heat gain coefficient (SHGC). The significantly lower SHGC for the highly insulated window would not pay off in the Northwest.

Whole-house energy savings. The homes with low-E storms saw an average whole-house savings of 10 percent, compared to 12 percent for triple-pane primary windows. The low-E storm windows saw better savings in the heating season than the summer. The opposite was true for the highly insulated windows, because of their low solar heat gain coefficient.

Air leakage performance. Manufactured homes are generally airtight, since factory environment is more controlled, compared to stick-framed homes built onsite. The lab homes did not see a significant benefit from decreased air leakage; this would probably not be the case in the field.

Whole-House Energy Savings

Average annual savings from low-E storm windows is 10 percent, compared to 12 percent for triple-pane windows.

Experimental Period	Operating Scenario	Average Daily Energy Savings	Average Energy Savings (%)
Summer Cooling Season	With Storm Windows in Lab Home B	3,623 ± 349 Wh	8.0 ± 0.5
Winter Heating Season	With Storm Windows in Lab Home B	14,251 ± 2,720 Wh	10.5 ± 0.2
Estimated Annual Results	With Storm Windows in Lab Home B	2,216 ± 31 kWh	10.1 ± 1.4
Estimated Annual R-5 Results	With R-5 Windows in Lab Home B	1,784 ± 189 kWh	12.2 ± 1.3

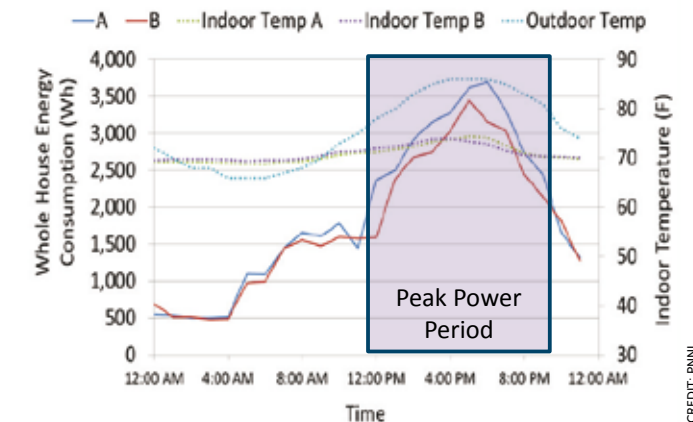
Weep holes. For some experiments, weep holes at the bottom edge of the storm windows were sealed to see if this improved air leakage performance; results were not significant. Weep holes are designed to prevent air leakage into that dead air space, because they are only at the bottom and don't have an escape at the top.

Peak energy use. During the heating season, the majority of savings occurred on sunny days at night, when it was the coldest outside. In summer, the greatest savings occurred on hot, sunny afternoons. This coincides with peak power periods for utilities experience, indicating that low-E storms can potentially decrease peak power use in the summer.

Cost and payback. The total installed cost of low-E storms ranged between \$1,500 and \$2,000, for a simple payback period of five to seven years. In comparison, R-5 windows showed greater annual savings, but with a payback of over 20 years.

INSTALLING LOW-E STORMS

Window or general contractors can easily install low-E storm windows; the only tools needed are caulk and caulking gun, *continued on page 34*



Reduced Demand. Low-E storms showed an average savings of 11.2 percent during peak power periods.



Inside Job. Storm windows, such as the interior unit shown here, can be custom ordered from window distributors and some big box retailers. Some common sizes are available off the shelf.

screw gun and measuring tape.

- Measure existing window opening. Exterior storm windows can be installed in two different configurations: an overlap installation or a blind stop configuration, in which the storm fits into the window opening. For a slider or any horizontal opening, measure the top, middle and bottom; use the smallest measurement to ensure the window will fit into the opening.

- Dry fit the window by holding the exterior window up to the window opening and checking that the screw holes all land on solid wood. Make sure that the storm window and the primary window open in the same direction.

- Caulk around the opening, then put the window back in place and screw it in. Caulk around the top and sides of the opening, but not around the bottom, as exterior storm windows have weep holes designed into the bottom. These help drain any condensation that occurs between the primary

and exterior windows.

- Blind stop installation is recommended for interior storms. Typically, a trim piece is installed between the primary window and the interior storm window to ensure a good thermal break and sufficient air gap between the two windows. Make sure that the low-E coating is facing the right side. (The side with the low-E coating feels squeaky.)

- Caulk around the entire opening, as interior storms function as the primary air barrier. Interior low-E storm windows don't have weep holes.

References

<http://1.usa.gov/1KDqHkG>

Presenters: Tom Culp, Owner, Birch Point Consulting, LLC, and Sarah Widder, Engineer, Pacific Northwest National Laboratory (PNNL)

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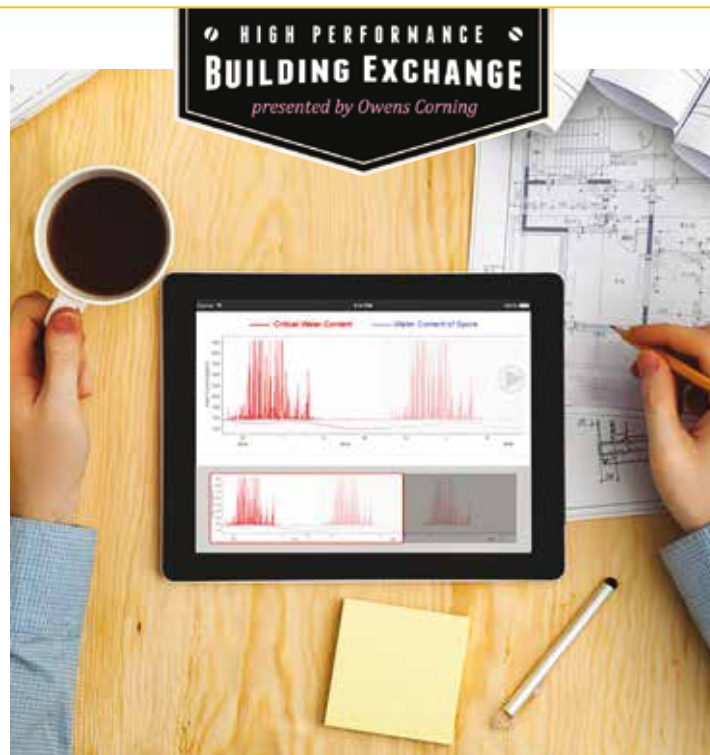
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An Innovation Design Request filed with RESNET is helping this Iowa DOE Zero Energy Ready Home and passive house project acquire a more accurate HERS Index.

BY CELESTE YEAGER KARAN, GEORGE SULLIVAN AND BOB CHOMKO

Contest eligibility and terms and conditions can be found online at solarpowerinternational.com/onlyatspi. All entrants hereby agree to the terms and conditions of the contest. All winners must be present at Solar Power International, September 14-17, in Anaheim, CA.

A NEW BUILDING IS TAKING shape at Full Revolution Farm, a “micro eco-farm” located just outside of Des Moines, Iowa. This project, which will include bed-and-breakfast accommodations, is being built to the standards of Passive House International, ENERGY STAR 3.1 and DOE Zero Energy Ready Home (ZERH), which includes the standards of the EPA’s WaterSense and Indoor AirPLUS programs.

This ambitious 9,527-square-foot project represents a collaboration between motivated homeowner Celeste Yeager Karan, Bob Chomko, RESNET QAD for the Building Science Institute, and George Sullivan, principal at Eco Smart Building. Since the project broke ground, Sullivan’s company has since been reorganized into Net Zero Analysis & Design Corp. to better reflect the company’s revised focus and capabilities.

A NET-POSITIVE SOLAR HOME

The project at Full Revolution Farm is designed as a passive solar home, but because of its mechanical system, in actuality the entire structure operates as an active solar thermal collector.

The home has no annual heat load, but rather a continuous cooling load throughout the year. This was achieved through an envelope that has no thermal bridging, thorough air-sealing, a significant amount of insulation, strategically placed windows and an advanced mechanical system.

Properly sized and shaded south-facing windows allow for a large amount of solar radiation into the home. Heat is also captured from normal human activity, mechanical equipment and appliance operation. This energy is collected via the multi-zone Mitsubishi CITY MULTI Variable Refrigerant Flow (VRF) geothermal system, which uses two 125-gallon solar thermal domestic hot water tanks as primary heat storage; the mass of the lower-level slab floor functions as secondary heat storage. After both primary and secondary heat storage is met, the CITY MULTI system will use the exterior glycol-filled geothermal field as a heat sink. An earth tube system (open-loop ground-to-air geothermal system) coupled with an energy recovery ventilator (ERV) provides ventilation and primary cooling.

We installed a 12-inch layer of high-density insulation under the basement slab and between the inner and outer walls of the double foundation. Twelve-inch-thick custom designed and engineered panels (CDEPS), manufactured without internal framing members, were applied as a curtain wall to the exterior of the home’s wood frame. Spray foam was used for air-sealing after the CDEPS were installed.

This design allows for net-positive energy production and therefore, a negative HERS rating.

The Story Behind the Building



BY CELESTE YEAGER KARAN

IVE LONG WANTED TO build the most energy-efficient and sustainable home possible. I wanted a home that could function off grid, even if that wasn’t allowed by zoning code, and used relatively little electricity and water, yet provided a high level of comfort. I became fascinated with the subject 20 years ago while taking an environmental science class in college, and it was something I had planned to do with my husband at “some time in the future.” When I found myself widowed, I knew I needed to rebuild my life around caring for my young children and creating a home-based business near supportive family. I bought an acreage at the edge of the Des Moines, Iowa, metro area that was an ideal site for a small bed and breakfast, and the idea for Full Revolution Farm was born.

I put together a team of friends and acquaintances I had gained over a decade of involvement in the Chicago real estate industry and organizations dedicated to “green” building. I had peripherally worked with George Sullivan and Michael Realmuto of Eco Smart Building and knew they had the experience and knowledge to create a cutting-edge building design. The design process began with a discussion of the multi-use nature of the building. The home is meant to accommodate a multi-generational family and paying guests by organizing public and private space on different levels. The design takes into account the building orientation (south and slightly east), soil type (heavy clay), microclimate (Zone 5B Marine) and shading factors, such as trees and the water tower. We were able to finish the full design and some necessary redesigns during construction before Mr. Realmuto’s untimely passing. Bob Chomko of the Building Science Institute came on board to provide testing, additional modeling and third-party verification of building performance.

PUSHING THE ENVELOPE

Building performance modeling is an integral part of the design process, as it helps design professionals simulate design decisions and analyze the strengths and weaknesses of various choices. Building models are used to estimate a preliminary HERS Index, which offers a projects’ decision-makers better tools for cost/benefit analysis.

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Superior Envelope. A CDEPS curtain wall installed against the framing adds insulation and eliminates thermal bridging.



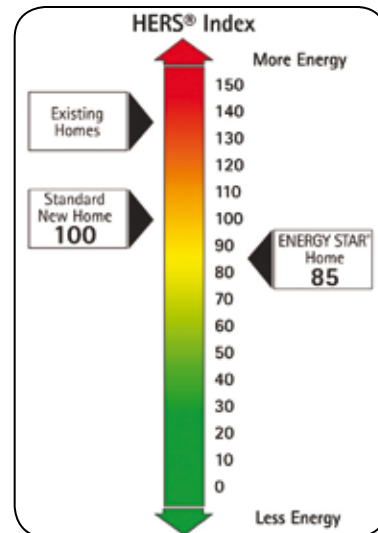
Pro Team. The CDEPS for Full Revolution Farm were manufactured by Eagle Panel Systems and installed by Timberline Builders.

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When we sat down at the dining room table in 2010 to begin the design, we had no idea how difficult it would be to get a HERS rating that accurately matched the performance of the house. There is no suitable group of mechanisms in most approved software programs to model a house that uses solar thermal gains and internal heat exchange for nearly 100 percent of its heating and supplies its cooling needs with an ERV/earth tube system. After discovering the limitations of the RESNET-approved modeling programs, we tried to work around them. We sought out more obscure software, contacted manufacturers for help and wrote our own in-house models for domestic water supply systems, cold water sprinkler systems and the earth tube system, which is based on actual data we collected. Finally, we were ready to submit an Innovative Design Request (IDR) to RESNET and ask for the house to be assigned a HERS Index that reflects actual calculations.

WHY FILE AN IDR?

As energy codes evolve, homes are built to higher efficiency standards. We are discovering many points of energy consumption that were not previously considered significant enough to quantify and include in the Rated Features of a Home. As homes'



Power House. The IDR process could adjust Full Revolution Farm's HERS Index from 23 to -2 before the addition of photovoltaics.

overall energy use is reduced, the previously "insignificant" energy use now comprises a significant percentage of the homes' overall energy consumption. In addition, new building technologies and innovative systems have emerged that are not yet assigned inputs in the RESNET-approved building models.

The Innovative Design Request (IDR) process is an attempt to refine the HERS Index where new technologies, design innovation and features of energy consumption previously were not quantified as a rated feature of the home.

An IDR must be submitted by "an approved RESNET-accredited quality assurance provider who is listed in good standing in the National RESNET Registry." Net Zero Analysis & Design Corp., a RESNET-accredited Quality Assurance Provider, and Building Science Institute Inc., our RESNET quality assurance and training provider, submitted the IDR for Full Revolution Farm.

We looked at several of the major components that were and were not covered in the RESNET Standard:

1. Live cold water sprinkler system
2. WaterSense-designed domestic hot water system
3. WaterSense-designed domestic cold water system
4. Windows installed in the insulation layer with over-insulation on the window frame
5. Solar thermal greenhouse



Total Isolation. Even the pads are thermally isolated on all five sides.



Heat Holder. A 6" concrete slab provides thermal mass and serves as the floor for the solar thermal greenhouse.

6. ERV model in REM/Rate
7. Earth tube system model
8. Variable refrigerant flow (VRF) mechanical and domestic hot water system model

All of the above systems were found to be contributing factors in reducing the HERS Index of the home.

CUSTOM MODELS

The IDR process is set up to allow for unique building elements or systems that reduce the project's energy use to be recognized in the home's HERS Index. When analyzing Full Revolution Farm, we looked at all of the building systems compared to the RESNET Standard for rated features of the home, DOE ZERH, ENERGY STAR 3.1, Passive House International Standard, WaterSense, Indoor airPLUS and local building code requirements. The modeling of Full Revolution Farm incorporated THERM models, EnergyPro models, REM/Rate models, "Manual J" heating and cooling load calculations and proprietary models that we developed in-house.

We reviewed local building code for systems that are required and modeled their energy impact to ensure we met the Passive House Standard. The modeled impacts were then analyzed to mitigate any increase in energy use over the Passive House Institute Standard.

We then reviewed the RESNET Standard for rated features of the home and the RESNET-approved modeling software against the Passive House International Standard and the Passive House Planning Package (PHPP) model to identify differences between the two standards in the way they calculated energy use and balance. The comparison led us to a number of differences. We discovered that an IDR would be necessary to account for the previously mentioned eight systems, because they were not covered in the RESNET Standards or in RESNET-approved modeling software.

We also discovered that, although several of the home's systems are included in modeling software as rated features of the home, applicable modeling inputs for the systems were not available, and using pre-set inputs resulted in an obviously skewed HERS Index.

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Heat Source. The solar greenhouse, shown here as the floor is being framed, will house a one-ton head, which is tied to the multi-zone Mitsubishi CITY MULTI system.



Domestic Cold and Hot Water Supply Piping Impact on the HERS Index

System	Uninsulated Pipe HERS Impact	R 6 Insulated Pipe HERS Impact
Live Cold Water Sprinkler System	85+	0
Water Sense Designed Domestic Hot Water System	65+	0
Water Sense Designed Domestic Cold Water System	65+	0

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INNOVATIVE SYSTEMS AND UNCHARTED TERRITORY

Each of the eight systems required different modeling strategies to calculate the loads of the system or the reduction in energy use. The REM/Rate model was then adjusted to account for the load or energy use reduction.

Domestic Water Systems

The domestic hot and cold water systems are normally not accounted for when calculating energy use in a building. We discovered that there is actually quite a large energy loss associated with them, and if that energy loss is added to the HERS Index, it has a significant negative impact on the rating. If all water pipes are insulated to R-6, however, there is no negative impact on the HERS Index in cold climates.

Window Installed U-Values

Window installation has a major effect on the labeled U-value of the window. Windows installed in contact with exterior building finishes such as brick, for example, will have a U-value

of 1.0, regardless of the stated value from the manufacturer. The project's windows are wood-framed argon-filled triple pane with a stated window U-value of 0.177. By using an innovative window installation technique that we developed, the window's stated U-value was decreased to 0.067—in other words, it was cut in half. Windows are installed mid-wall per Passive House Standards and then over-insulated to thermally break the frames from the exterior. THERM model results were reviewed by Passive House International for accuracy. This window installation method decreased the HERS Index score by 3 points.

Solar Thermal Collector

Full Revolution Farm has a solar thermal greenhouse which is conditioned by a Mitsubishi air-to-water head. This was modeled as a solar thermal vacuum tube, per manufacturer specifications, for sizing the vacuum tube collector to the two 125-gallon solar thermal DHW tanks. This design was reviewed by a solar thermal vacuum tube manufacturer, who also suggested an adjustment based on heating degree days to reflect the actual performance of the Mitsubishi air-to-water head in the space. The adjusted solar thermal system was modeled in REM/Rate and the HERS Index decreased by 5 points.

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Ground Control. The earth tube system consists of supply and exhaust tubes that connect to energy recovery ventilators (ERVs). The tubes use the constant temperature of the earth to moderate the temperature and humidity of intake air before it passes through the ERVs.

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ERV System Impact

We asked the ERV manufacturer UltimateAir to review the ERV energy input into REM/Rate for their RecoupAerator 200DX. The modeled performance in REM/Rate did not match the manufacturer’s performance curves. The manufacturer suggested a calculation that would correct the inaccuracy of the performance. We performed the calculations and adjusted the energy inputs in the REM/Rate model. The adjusted ERV system was modeled in REM/Rate and the HERS Index decreased 3 points.

Earth Tube System Model

The project has an open-loop air-to-soil geothermal system before the ERV; this system heats or cools intake air to 55° F. The modeling of the ERV/earth tube system was reviewed by the ERV manufacturer UltimateAir, which has a number of these system in the field, and they have approved the calculations and energy impacts. Our proprietary earth tube system model was modeled in REM/Rate and the HERS Index decreased 8 points.

Variable Refrigerant Flow (VRF) HVAC-Modeled System

Neither REM/Rate nor EnergyGauge have the ability to model VRF mechanical systems. Mitsubishi Electric Company recommended that the system be modeled in EnergyPro to determine an accurate system performance in the modeled project building. Mitsubishi Electric Company reviewed the EnergyPro model for accurate VRF input and function, and found that their equipment is correctly modeled in the Full Revolution Farm EnergyPro model. The only exception is that the domestic hot water system cannot be modeled in any of the current energy modeling software.

The EnergyPro model revealed that the building has a negative heating load. The building’s as-built shading features were input into the Manual J model, which was uploaded into both models (REM/Rate and EnergyPro) for this example and comparison. Next, the energy use of the VRF system, as modeled in the EnergyPro model, was used to adjust the REM/Rate model. When the VRF HVAC system was modeled in REM/Rate with the adjusted values from the EnergyPro model, the HERS Index decreased 6 points.

IMPACT AND NEXT STEPS

The overall impact of our analysis was a 25-point decrease in the project’s HERS Index. The HERS Index of this project is negative without using photovoltaic or small wind (5 kW systems) for onsite power generation (see Chart). There are a number of additional systems in this project which, once analyzed, are likely to lower the HERS Index even further.

But an approved IDR has a greater impact than adjusting one project’s HERS Index; it allows us to adjust the HERS Index of other projects that use any of the eight systems that are outlined in it. The IDR allows us more tools to accurately model low-energy projects in general.

It includes a request for three measures:

- 1) “As-installed windows” vs. NFRC ratings
- 2) Earth tube pre-heater installed with ERV

Full Revolution Farm IDR for HERS Index Adjustment Request

REM/Rate Model Name	HERS Index	HERS Index Change from Standard per Modeled System	Cumulative HERS Index Adjustment per Model
Model per Standard	23	Base Model	Base Model
Live Cold Water Sprinkler System Modeled in REM/Rate Piping Insulated to R-6	23	0	0
WaterSense Domestic Hot Water System Modeled In REM/Rate Piping Insulated to R-6	23	0	0
WaterSense Domestic Cold Water System Modeled In REM/Rate Piping Insulated to R-6	23	0	0
Therm Modeled Window U-Value = 0.67	20	-3	-3
Adjusted Solar Thermal System	18	-5	-8
Adjusted ERV System	20	-3	-11
Earth Tube System Model	15	-8	-19
VRF HVAC Modeled System	17	-6	-25
Total Request Adjustment to the HERS Model Index per Standard			-25

3) The Mitsubishi ground-source heat pump with variable refrigerant flow

Once an IDR is submitted to RESNET, the committee has six weeks to review all of the models and supporting paperwork and to respond to the request. During that time, they may ask questions and request additional supporting documents. The current set of eight systems that we have reviewed all have an impact on the RESNET standard for the rated feature of the home and on the current set of RESNET-approved models. We will be submitting these items to the RESNET Standards Committee to allow passive homes and zero-energy-ready homes to be properly modeled and assigned correct HERS Indexes.

We are in the final steps of preparing several other innovative design requests. To date, there has not been a detailed analysis of a similar project submitted as an IDR to RESNET. In fact, since 2013, only seven IDRs have been submitted, and two of those submitted were not approved. The time commitment of hundreds of man-hours required to thoroughly investigate building modeling issues is often an impediment to teams who have valid concerns about the accuracy of a building’s HERS rating.

Progress on Full Revolution Farm can be followed on the project blog: www.NetZeroAnalysis.Wordpress.com

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Cleaner Coatings

Paints, stains and finishes protect materials and add beauty to building exteriors. Here's a guide to choosing products that are beautifully sustainable, too.

Wood Winner. Benjamin Moore's ARBORCOAT waterborne wood finishing products are low in VOCs.

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CREDIT: BENJAMIN MOORE

BY JULIET GRABLE

WE EXPECT A lot out of the coatings that protect siding, trim and other parts of a building exterior. Paints, stains and finishes must be resistant to moisture, mold and the constant exposure to UV radiation. And of course they must add beauty to the materials. Modern chemistry allows coatings to perform, but not without costs. Most paints and finishes are high in embodied energy, and since home exteriors are repainted frequently—on average, every five to 10 years—coatings can add significantly to a building's carbon footprint. Consequently, choosing a durable

product, proper application and maintenance are imperative.

Many coatings contain volatile organic compounds (VOCs) and toxic chemicals that threaten the health of workers in manufacturing facilities, contractors applying the materials and people exposed to them inside or outside of buildings. Architectural coating products also present a disposal problem.

Fortunately, the industry has undergone a transformation in recent decades. The first big change was the phase-out of lead pigments, banned in 1978. The industry has moved away from oil-based solvents; today, the vast majority of all architectural coatings are water based. These contain a fraction of the VOCs and much lower embodied energy.

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THE CHEMISTRY OF PAINT

Paints consist of pigments, binders, solvents and additives. Before it was phased out in 1978, lead was a commonly used pigment that enhanced paint's durability. Titanium dioxide is the most widely used paint pigment today; it is also used in sunscreens and cosmetics. TiO₂ production is energy intensive and may account for a large percentage of the embodied energy in paints. (The EPA estimates that the total emissions from domestic TiO₂ production in 2006 equaled 3.6 metric tons.)

As the word implies, binders help hold the pigments together. Most high-end water-based paints contain synthetic acrylic resins as the binder. These paints perform extremely well, and although acrylic resins are made from petroleum, water-based paints—also called “latex-based” paints—don't have the same environmental issues as those that use oil as a solvent, which can be a significant source of VOCs in coatings. Additives include biocides, fungicides and agents which enhance performance. Heavy metals such as cadmium are used as drying agents.

Some of the problem VOCs found in conventional paints include formaldehyde, benzene, acetone, cyclohexane and xylene. Not only are these compounds harmful to health, they accrue in the atmosphere, adding to the greenhouse effect.

The EPA limits VOC concentrations in architectural coatings; for instance, the limit for exterior coatings is 380 grams per liter (g/L); the limit for clear and semitransparent stains is 550 g/L. Some states, regions and counties have set even stricter standards; for example, South Coast Air Quality Management District (SCAQMD),



CREDIT: MYTHIC PAINT

Across the Board. Mythic Paint offers several exterior lines, from *Mythic PRO*, designed to compete with other contractor-grade products, to *Mythic Classic*, which boasts outstanding durability. WWW.MYTHICPAINT.COM

the air pollution control agency for the Los Angeles area, limits VOC levels in architectural coatings to 50 g/L.

Several manufacturers offer formulations that meet or exceed even the strictest limits; however, it's important to understand that colorants often contain VOCs and so add to the total concentration of the mixed product. In addition, some low- or no-VOC products may still contain toxic substances. The best way to evaluate a coating is to download the product's Material Safety Data Sheet (MSDS). Manufacturers are required to list potentially hazardous ingredients. Product Data Sheets (PDS) will include VOC concentration, solid content and other information that can help you evaluate the product's quality. Products that have been certified by third-party organizations are required to meet standards limiting VOC concentration or emissions and, in some cases, chemicals of concern (see Certification Guide on page 54).

In general, there is movement toward less toxic formulations and low- or no-VOC formulations, says Steve Dearborn, president of Miller Paint, which is based in Portland, Oregon, and serves the Pacific Northwest. “It's now possible to put together a completely nontoxic product,” he says.

Not surprisingly, there are far more nontoxic and low- and no-VOC options for interiors than for exteriors. Concern for indoor air quality has driven the demand of these healthier interior products,

Low-VOC: The product contains no more than 50g/L
No-VOC: The product contains no more than 5g/L



CREDIT: BEHR

Good Investment. *MARQUEE*, BEHR's top-of-the-line exterior product, is appropriate for wood, vinyl, brick and masonry exteriors. It comes with a limited lifetime warranty. WWW.BEHR.COM

but the contribution of coatings to greenhouse gas emissions is behind much of the legislation mandating coatings with lower VOCs.

Choosing a responsible exterior product requires balancing performance (i.e., durability) and environmental considerations. However, manufacturers that have already developed low- and no-VOC interior products are now taking up the challenge outside of the building.

AHEAD OF THE CURVE

Imperial Paints, based in the U.K., saw so much interest in its “all natural” paint products that it opened a manufacturing facility in South Carolina. The daughter company, called ECOS Paints, offers organic and 100 percent VOC-free nontoxic paint to online customers.

“The original formulation was developed by a British chemist who suffered from Chronic Fatigue Syndrome,” says Danny Holder, technical sales manager for ECOS Paints. “He developed a product line that was pure before it was fashionable to do so.” At first, the paints were sold mostly to asthma and allergy sufferers, but as people became concerned and educated about harmful chemicals, sales increased.

The colorants for ECOS paints are imported from Europe. Many are medical and dental grade; some are even food and cosmetic grade. There are no glycols, a common source of VOCs in paints.

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Keeping the Lead Out

IF WORKING ON a home that was built before 1978, painting contractors are required to provide clients with an EPA-authored brochure called *The Lead-Safe Certified Guide to Renovate Right*. The brochure includes a section

detailing the procedures contractors should follow to ensure no one—including the contractor—is exposed to lead dust, which can accumulate in the soil and be tracked into the house:

- 1. Contain the work area.** Dust and debris should not escape from that area. Warning signs must be put up and plastic or other impermeable material and tape must be used, as appropriate:
 - Cover the floors and any furniture that cannot be moved.
 - Seal off doors and heating and cooling system vents.
 - For exterior renovations, cover the ground and, in some instances, erect vertical containment or equivalent extra precautions in containing the work area.

- 2. Avoid renovation methods that generate large amounts of lead-contaminated dust.** Some methods generate so much dust that their use is prohibited. They are:

- Open flame burning or torching.
- Sanding, grinding, planing, needle gunning or blasting with power tools and equipment not equipped with a shroud and HEPA vacuum attachment.
- Using a heat gun at temperatures greater than 1,100 °F.

Methods that reduce dust include using water to mist areas before sanding or scraping, scoring paint before separating components and prying and pulling apart components instead of breaking them.

- 3. Clean up thoroughly.** The area must be cleaned up daily using special cleaning methods before taking down any plastic that isolates the work area from the rest of the home.

- Use a HEPA vacuum to clean up dust and debris on all surfaces.
- Wet wipe and wet mop with plenty of rinse water. There should be no dust, paint chips or debris in the work area; otherwise, the area must be re-cleaned.

Source: EPA <http://1.usa.gov/1J66Op4>



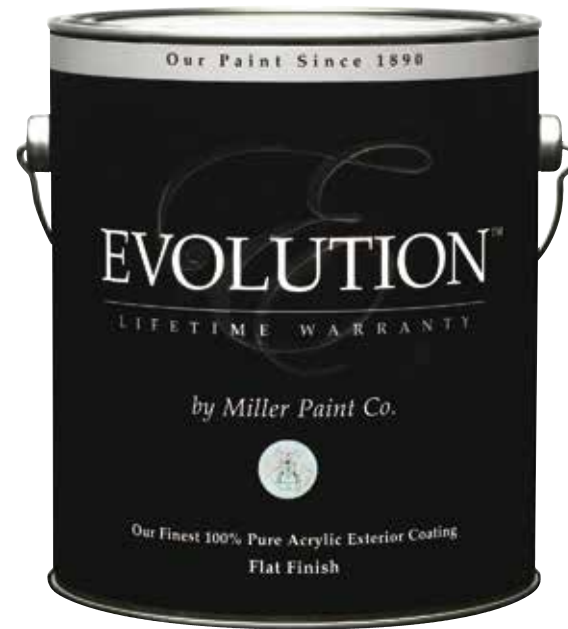
CREDIT: REINSENE.ORG



CREDIT: SHERWIN-WILLIAMS

Hold the VOCs. Sherwin-Williams *ColorCast Ecotoner* colorants can be used to tint all of the manufacturer's water-based latex architectural coatings. The colorants are GREENGUARD Gold certified.

WWW.SHERWIN-WILLIAMS.COM



CREDIT: MILLER PAINT

The High End. *Evolution* is Miller Paint's finest 100 percent acrylic exterior paint. The low-VOC product is appropriate for wood, metal and composite surfaces and is backed by a limited lifetime warranty.

WWW.MILLERPAINT.COM

Pre-Painted Siding and Trim

A FEW COMPANIES HAVE begun offering prefinished (i.e., pre-painted) fiber cement siding and trim; notably, James Hardie and Plycem's Allura. These products may represent a viable strategy for reducing the lifecycle impacts of fiber cement products, which do have high embodied energy. The controlled factory environment assures excellent coverage and optimal curing conditions; consequently, siding treated this way may not have to be repainted as quickly as new siding that is painted in the field.



CREDIT: JAMES HARDIE

Upgrade. Available for several siding and trim products, James Hardie's *ColorPlus* finish protects against peeling, cracking and chipping.

James Hardie products treated with the company's *ColorPlus* finish come with a 15-year limited warranty that covers paint and labor. Multiple coats of a proprietary finish are applied to every surface and edge, and the finish is cured between coats.

The finish is available in about two dozen colors; touch-up kits are available for cut edges and nail heads.

Allura's *ColorMax* finishing system, which includes 22 solid colors and six semi-transparent wood stains, is also backed by a 15-year limited coating warranty. The system consists of a primer/sealer for premium weather protection and machine-applied coats of a 100 percent acrylic coating from PPG Pittsburgh Paints. Allura also offers touch-up kits.

self-priming application, flow and leveling." All sheens are less than 50 g/L VOC.

RECYCLED PAINT

One way to reduce the environmental impact of paint is to use recycled paint. PaintCare is a non-profit organization and project of the American Coatings Association. The organization plans and operates stewardship programs in states that have passed paint recycling regulations. Currently, eight states plus the District of Columbia either have programs in place or plan to launch them this year.

Oregon was the first state to pass mandatory paint recycling regulations. Since the start of the state's program in 2010, PaintCare has helped set 157 drop-off locations. Many are retail stores; others are hazardous household waste collection sites. The program accepts house paint and primers, stains, sealers and clear coatings.

The program is funded through fees on each container of architectural paint sold in states with paint stewardship programs. Though fees are set on a state-by-state basis, so far all programs have set the same fees, which range from 35 cents to \$1.60 per container, depending on its size.



CREDIT: AFM SAFECOAT

Wood Protection. Safecoat *DuroStain* is made without formaldehyde preservatives or toxic fungicides, so users must be careful to clean surfaces and avoid contaminating the product.

WWW.AFMSAFECOAT.COM

Metro—a regional governmental organization serving the Portland, Oregon, metropolitan area—has partnered with Miller Paint to help create a market for recycled paint. *MetroPaint* retails for \$10.95/gallon and is purchased by an equal number of pros and homeowners, says Dearborn. "Although volume manufactured has grown every year, it still can't keep up with demand."

continued on page 54



CREDIT: MILLER PAINT

New Life. *MetroPaint* is 100 percent recycled latex paint comes in eight color choices. Certified *MetroPaint* is Green Seal certified. (Note: Green Seal VOC standards for recycled paint are lower than those for new interior and exterior coatings.)

WWW.PAINTCARE.ORG

continued from page 51

A gallon of eggshell paint costs \$54, and shipping can add substantially to the cost; however, a recent partnership with UPS has created an affordable alternative. Any order may be picked up at a UPS store location for only \$9.95, regardless of distance or size of the order.

Mythic Paint developed its no-VOC, carcinogen-free formulation in collaboration with the University of Southern Mississippi through a government grant. "At the time, the Pentagon was looking for paint which would not require them to relocate their personnel during renovations," says Sabrina Kleinknecht, corporate account executive for Mythic Paint. Every product qualifies as zero-VOC, even with colorants, which are made with both natural and man-made materials. Zinc oxide serves as the fungicide and is preferable to the more toxic alternatives.

Mythic Paint offers 100 percent acrylic exterior paints at a competitive price point (its *Classic* low-lustre is \$39.99/gallon).

Several companies now offer VOC-free colorants, including Mythic, Miller Paint, Dunn-Edwards and Sherwin-Williams.

"The *ColorCast Ecotoner* colorants were developed to help on several fronts," says Rick Watson, director of product information and technical services for Sherwin-Williams. "They won't add to the VOC content of any paint when tinted, and they help to maintain the paint's viscosity after tinting. That means the colorant will not reduce or increase the viscosity of the applied paint."

THE CASE FOR QUALITY

Dearborn has seen a migration toward higher-end products in recent years. Sales of *Evolution*, Miller Paint's highest-end exterior product, have grown by 20 percent over the past two years.

"People are becoming more educated and are willing to pay for a superior product," says Dearborn. "This is true in the consumer market, but it is very pronounced among our pro customers."

In general, better-quality paints contain a higher percentage of solids and a greater proportion of high-quality pigments to cheaper fillers, such as calcium carbonate. They provide better coverage, resist fading and last longer, assuming they were applied properly.

Most manufacturers offer several lines of exterior products. Behr, for example, offers *BEHR MARQUEE*, *PREMIUM PLUS ULTRA* and *PREMIUM PLUS* exterior paints. While each is tailored for a specific purpose, all are formaldehyde free and certified GREENGUARD Gold.

MARQUEE, the brand's top-of-the-line exterior paint, offers the best in durability and performance, along with superior dirt pick-up resistance and early rain resistance. It retails for around \$46/gallon. In comparison, *BEHR PREMIUM PLUS Paint & Primer in One*, which delivers basic primer properties along with a durable finish, costs around \$30.

Sherwin-Williams also offers several lines of exterior paints. "*Emerald Exterior*, which was introduced in 2012, is number one overall in terms of durability and performance," says Watson. "It's perfect for high-end work, and it offers excellent

Product Spotlight: Cleaner Coatings

continued from page 53

STAINS AND FINISHES

There are many coating choices for wood surfaces in addition to paint. These products protect wood from physical damage, water, UV damage and rot; they also enhance wood's beauty by adding sheen and, sometimes, color. Most of these products need to be applied more regularly than paint and significantly increase the carbon footprint of wood, which, when left to weather naturally, is a material with extremely low embodied energy.

There are two general categories of wood finishing products. Film finishes form a protective hard coating above the grain; penetrating, oil-based finishes soak into the wood. Like paints, wood-finishing products contain resins and a solvent. Traditionally, plant- or insect-based oils were used as resins and thinned with turpentine. Today, resins or binders are often petroleum-based compounds, including acrylics, vinyls, alkyds, cellulose, epoxies and polyurethanes. Alkyd- and polyurethane-based varnishes are high in VOCs; acrylics are lower. There has also been a resurgence



Au Naturel. Sansin SDF is a penetrating, water-repellent one-coat finish for wood exteriors. It comes in natural, semi-transparent and solid colors. WWW.SANSIN.COM

in products that use natural resins as the base.

Solvents and/or thinners used in wood finishing products include alcohols, ketones, glycol ethers, petroleum distillates, turpentine and water. As with paints, a number of manufacturers now offer lower-VOC, water-based alternatives.

In general, stains are lower in VOCs and last longer than clear finishes. (According to the Western Red Cedar Lumber Association, solid stains on textured wood need to be reapplied every four to six years; semi-transparent stains every two to four years.) Benjamin Moore offers its *ARBORCOAT* line of low-VOC waterborne stains and finishes in five opacities. They use the same patented colorant technology as the company's low-VOC paints, so the total VOC concentration with colorants will not exceed 100 g/L. Penofin Verde is a no-VOC wood stain that is appropriate for both interior and exterior use. As is the case with all Penofin wood-finishing products, its base is Brazilian rosewood oil, which is sustainably harvested from the tree's pods. It boasts less than 1 gram VOCs/L and 99 percent UV protection.

Sansin offers an entire line of *Enviro Stains* and finishes that are made from tree oils. Modified natural oils and resins are carried deep into the wood's cell structure, using water as a carrier. As the water evaporates, Sansin bonds directly with the wood substrate, forming a tough, durable barrier that won't crack, peel or blister. Sansin even offers a recycled product. *Eco2 Exterior* is a durable, two-coat finish designed for vertical wood surfaces; it is made from recycled Sansin products and is available in four colors.

AFM Safecoat does not use formaldehyde in its manufacturing processes or products, and the company offers an entire line of LEED-qualified stains and finishes. Its *DuroStain* semi-transparent stain is appropriate for all wood surfaces and contains no aniline dyes, gilsonite, aromatic solvents or formaldehyde. Its very low VOC content also meets all federal and state air quality regulations. **GB**

Certification Guide

WITH ALL OF the third-party certifications out there, it's difficult to compare apples to apples. To confuse matters more, some manufacturers have come up with their own in-house labels. Here's an overview of some of the certifications and their requirements:

Green Seal certification. Green Seal standards set strict limits for VOCs, heavy metals and harmful chemicals. They also include performance requirements. Three standards are relevant to coatings:

- GS-11: Standard for Paints and Coatings
- GS-43: Recycled Content Latex Paints
- GS-47: Stains and Finishes

WWW.GREENSEAL.ORG

■ **GREENGUARD certification.** UL Environment uses chamber testing (as opposed to concentration in the product) to evaluate the VOC impact of products. The GREENGUARD standard includes limits for total VOCs, formaldehyde and three other categories; the GREENGUARD Gold standard includes limits for over 30 additional compounds.

WWW.GREENGUARD.ORG

■ **GreenWise certification.** The Coatings Research Group, Incorporated (CRGI) certifies several types of coatings to two levels of certification: GreenWise and GreenWise Gold. The standards set limits for VOC concentrations and includes a list of forbidden chemicals. They also include performance requirements.

WWW.CRGICONNECT.COM

■ **MPI Green Performance Standard.** The Master Painters Institute (MPI) includes a two-tier green performance standard in its Approved Products List. The standard sets limits for VOC concentrations and includes a list of forbidden chemicals.

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Geothermal Community Could Be a Game Changer

The 1,500-acre Badger Mountain development in Washington aims for zero net energy, thanks to high-performance Bosch geothermal systems.

YOU MAY HAVE HEARD OF solar leasing, a relatively new, effective way of introducing solar PV into the mainstream. Now the thermotechnology industry is using the same type of approach, something called thermal service providers, to sell thousands of new homeowners on geothermal heating and cooling.

The key, says Mark Stimson, business development manager for Bosch Thermotechnology, is taking the highest cost of geothermal loop off the table: excavating and drilling to install the ground loop.

At Badger Mountain, he says, “they were looking to build a master-planned community that would really stand out. They connected with Orca Energy, which has a thermal service provider program. So you get all of the benefits of geothermal without the first-cost hurdle of the ground loop. The way it works is that Orca owns (and maintains) the ground loop, while the other equipment, heat pumps and so on, are amortized over the 20-year home mortgage.”

The result for homeowners, he says, is little impact on their monthly mortgage, but ongoing savings on energy use for the life of the home.

“Orca meters the thermal BTU of the ground loop and charges them a rate that’s lower than the local electrical rate, so they can end up with as much as 30 percent lower heating or cooling bills—depending on the climate, weather and how people use them.”



Ground Breaker. The Badger Mountain development in Washington State, now under way, is designed for 5,000 mixed-use units all on geothermal systems.

IoT Upgrade Coming

“The Internet of Things smart home is very much something we’re working on as a company,” Stimson says. “The challenge is to create interactivity between vehicles and housing with open-source software.” Bosch is

working to introduce “smart” controllers that add on to the basic heating or geothermal systems. These wireless controllers will have a remote (smartphone-enabled) Internet capability and other features to make them appealing to homeowners.



On Display. A model home at the Badger Mountain development showcases Bosch appliances in both the kitchen and laundry room.

He notes that stricter building codes in some states and cities have helped sell geothermal for projects such as Badger Mountain. He notes that with the new home market, a product needs to be viable

to large-scale production builders, not just the traditional niche of custom builders. Mandatory codes make that a reality.

“Developers are finding that they *must* meet energy efficiency compliance, so they’re looking for innovative solutions,” Stimson notes. “Take a place like Austin, Texas, where there’s a zero-net-energy requirement. Geothermal offers a way to balance costs, for example, because you can reduce the size of your PV array.”

Selling with Simplicity

“Our value proposition for the builder and developer is to really simplify the process for them,” Stimson notes. “We understand the technical challenges and help them explain benefits to homeowners. It’s a full-service approach.”

Along with the energy savings, one less-touted benefit of geothermal is noise reduction. The geothermal equipment is typically housed safely indoors, protected from the elements. At Badger Mountain, developers realized that they could actually promote quieter homes, because neighbors would not have to listen to loud

air conditioners on summer afternoons.

Homeowners buying into a thermal service provider plan get a nice durability package. The ground loop installer, in this case Orca Energy, maintains the loop and all connectors and plumbing for as long as current residents remain part of the program—and the contracts are transferable. Heat pumps have a 10-year warranty.

Next step for geothermal manufacturers such as Bosch: get other utilities on board. That means convincing utilities that there’s a strategy to defer distribution costs and retain customers by owning the ground loops.

“We’ve been talking to utilities around the country, and we’re making progress,” Stimson says, “but they don’t like to move quickly. They like to see somebody else do something before they take the risk. But we think they’ll soon see that this could be a good ancillary business for them.”

www.boschheatingandcooling.com

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CODE WATCH

The Latest on Green-Related Construction Rules and Regulations

By Mike Collignon

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Performance Anxiety

A Minnesota homebuilders association chafes at the State's new energy code, while Pennsylvania experiments with incentivizing high-performance homes.

MINNESOTA

The state's new residential code took effect on January 24, 2015, and the energy code went into effect on Valentine's Day. In late January, the Builders Association of the Twin Cities (BATC) took two legal actions against the state's residential code and energy code. BATC filed a petition with the Minnesota Court of Appeals, disputing the Department of Labor and Industry's (DLI) amendments to the IRC and IECC. BATC also filed a motion to delay enforcement of the new codes until the appeal could be heard.

The lawsuits arrive after several years of rule-making that resulted in an agreement between BATC and the DLI on most code changes. However, in the energy code, rather than a prescriptive approach, BATC advocated for more flexible, performance-based rules that they feel would be less expensive, yet just as effective. BATC also opposed a sprinkler requirement (as do almost all HBAs), claiming it is unnecessary and expensive. Their cost estimates claim that the codes will add \$6,000 to \$10,000 to the cost of an average new home, and almost \$20,000 for a 4,500-sq.-ft. home with a basement. A former BATC official referred to the new code changes as "the largest regulatory tax on homebuyers in Minnesota history," and stated that the costs exceed the value of the changes. BATC Executive Director David Siegel stated, "BATC believes the codes have substantial flaws, that the Minnesota Department of Labor and Industry did not properly analyze the impact of the rule and [that] these codes need to be sent back and fixed for Minnesota homeowners."

While the DLI was silent on sprinkler costs, they produced DOE data, as well as their own, that directly refuted BATC's claims. Scott McLellan, executive director of the Construction Codes and Licensing Division, explained:

"Based on research that was developed during the adoption of the codes, the new Minnesota Residential Energy Code is estimated to add around \$0.75 per sq. ft. to the cost of a new home using conventional construction techniques. This amounts to around \$2,500 for a two-story walkout house of



Strong Argument. In a slide presentation available through its website, the Pennsylvania Housing Finance Agency makes a case for building to Passive House standards.

3,300 sq. ft. The U.S. Department of Energy estimates Minnesota's new residential energy code will provide homeowners an average household energy savings of \$669 each year with a (simple) payback of 5.7 years. The DOE's publication *Minnesota Energy and Cost Savings for New Single- and Multi-family Homes* identifies the cost savings of going to the 2012 International Energy Code from our state's previous Minnesota Energy Code."

In mid-February, the appeals court denied the BATC's request to delay. As of the end of March, the updated codes were still in effect. The appeals court will hear oral arguments on July 15, 2015, but won't publish their decision until September at the earliest.

OBSERVATION(S):

The only thing new about this story is the location. We've seen this type of maneuvering in the past. The HBA puts out inflated cost estimates and claims the homebuilding industry will be irreparably harmed. The state agency touts a state-specific DOE analysis that refutes the aforementioned cost data. The

(financial) truth usually lies somewhere in between, but neither side ever looks at the cost of ownership. The costs get debated at the "simple payback" level, and that's really unfortunate. (I have long argued that, since most people finance their homes rather than pay with cash, we should consider the per-month cost of the upgrade rather than the total cost. This monthly increase can easily be compared with average monthly savings of the upgrade.)

On the topic of sprinklers, the ROI is harder to quantify. On one hand, the ROI is infinite if a life is saved. It's also substantial if the sprinklers result in reducing property loss. It usually comes down to the perceived odds-of-a-fire event versus the initial cost. So far, most jurisdictions have amended that requirement out.

PENNSYLVANIA

The state briefly offered a tax credit for low-income housing that met the Passive House criteria. The Pennsylvania Housing Finance Agency (PHFA) offers loans and tax credits to qualifying multifamily project applicants. Applications submitted under the PennHOMES and low-income housing tax credit program are scored and numerically ranked. Projects can earn up to 130 points under five categories. This year, projects that were Passive House "certifiable" could earn a maximum of 10 points. An equivalent number of points were available to structures pursuing Enterprise Green Communities criteria. To qualify, the application needed to include pre-certification from a Passive House organization (either national or international); at the completion of construction, blower door test results and all other third-party test results must be submitted, although the project need not be officially certified. The state tax credit is highly sought after, with less than one-third of the applications receiving funding. (According to one article, only about 40 of 130 applications were expected to receive funding for 2015.)

In a pre-application slide presentation (which is still available

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For more information, contact Mike Collignon, executive director at mcollignon@greenbuildercoalition.org

through the PHFA website), the organization makes the case for the high-performance program as a step toward net-zero-energy readiness. The presentation also cites other progressive state and local energy codes. Pennsylvania currently follows the 2009 IECC.

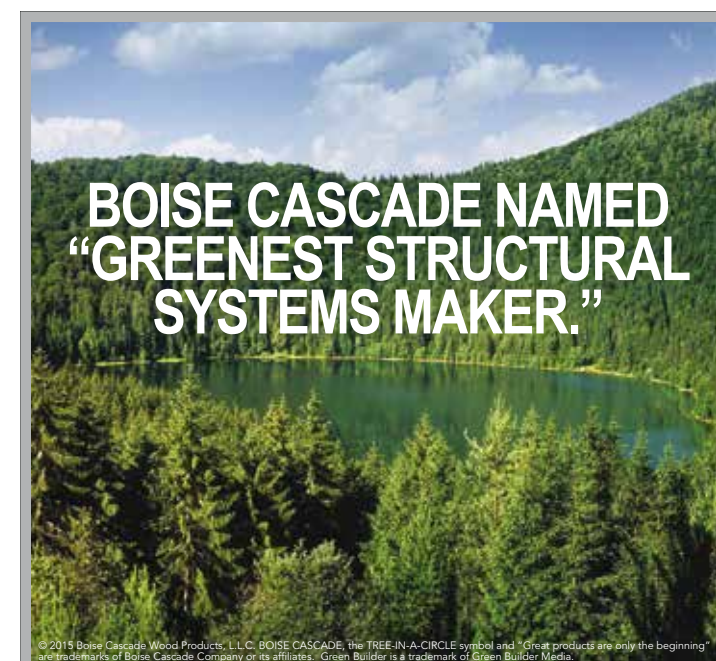
OBSERVATION

This was an unprecedented recognition of the high-performance energy program. Passive House has struggled to gain traction in the United States, with less than 200 projects obtaining certification. (Worldwide, there are over 40,000 such properties.) Accomplishments like this can only help the program, which certainly has its dedicated fans.

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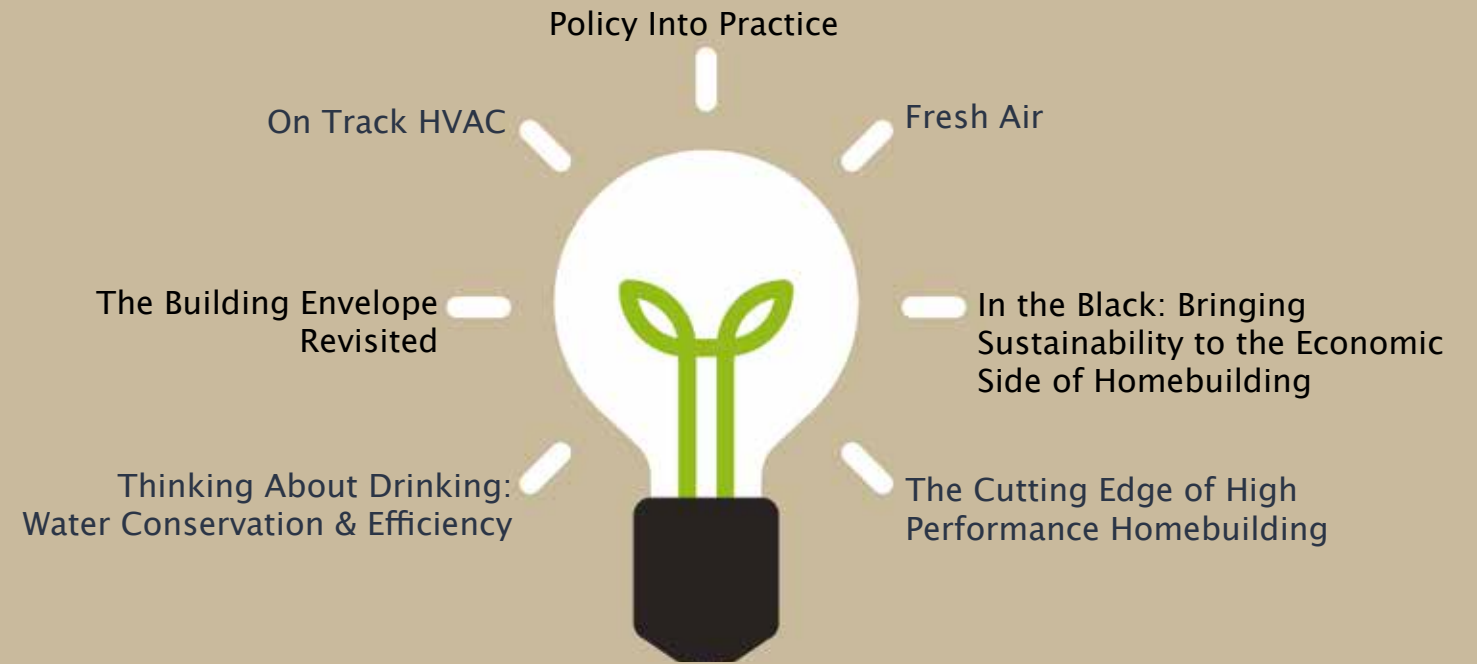
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Building in the High Country

SUMMER AT MARIPOSA MEADOWS has been interesting so far, to say the least. We face some unique challenges here, as well as some that are more universal to the building industry. The apparent victory in the beaver battles last fall has proven to be less than conclusive.

After several months of ignoring the main irrigation gate, our furry friend recently mounted a new offensive and overwhelmed the previously invincible “beaver deceiver” by plugging the intake with large chunks of willow and aspen, followed by reams of grasses—all topped off by an impressive volume of thick mud.

Rest assured: we have not given up the fight. Each day, we return to the ditch bank to pry out all of the soggy materials and debris that were stuffed in the night before, always amazed at the industriousness of our adversary. We release the flow of water from the main stream through the decades-old, hand-dug ditches that distribute the cold, clear liquid over the many acres of meadow grasses and wild flowers—even though we know at this point that the beaver will be back under cover of darkness to start the process all over again.

Moose sightings have been frequent, as well. Cows with calves and at least two very impressive bulls—still in velvet as their gigantic racks of points and palmations grow bigger and heavier with each passing day—cruise the beaver ponds and thick brush, causing the occasional traffic jam on the forest road. Jeep-loads of astonished flatlanders take countless photos on their phones to send back home as proof of their high-country adventures.

A particularly wet spring and summer weather pattern have helped the meadows immensely, and the grasses are waist high in most places. As a bonus, all the moisture has helped mitigate the risk of wildfire, at least in the short term. Meanwhile, we have been consulting with the U.S. Forest Service and representatives of the USDA to develop a comprehensive conservation plan. We want them to help us to protect our natural resources and even improve the habitat for wildlife at Mariposa as we make gradual progress with our master plan and the individual projects we have undertaken there.

At the same time, we are experiencing some challenges that are not so unique to our area. The local economy has improved measurably from last summer, as indicated by the impressive increase in sales tax revenues over the same period last year. While this is great news for local



government and the general population, it has had a predictable effect on the finite labor pool in such a small market. We are not insulated from the manpower shortages that are plaguing the homebuilding industry in every corner of the country. And like other builders, we are noticing longer lead times for certain materials.

As a result, our progress has been hampered, but we forge ahead at a more measured pace. Our hope is to have our current structures advanced far enough so that when the snows come again, we will have the option of continuing inside work at our discretion. The shorter days and access by snowmobile will present a new set of hurdles, but at least by then the beaver will be tucked away in his lodge for a while, and irrigating won't be a concern until spring returns again. **GB**

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