

# Energy Performance and Closed-Cell Spray Foam: A Better Building Technology

The case for closed-cell spray polyurethane foam (ccSPF) to improve energy performance



**WHITE PAPER SUMMARY:** Superior energy performance depends largely on creating a better building envelope. Use of closed-cell spray polyurethane foam (ccSPF) as insulation provides consistent and unparalleled airtightness, thermal performance, and moisture-control benefits. Authoritative research confirms the cost effectiveness and suitability of ccSPF.

## Overview: Why ccSPF—and Why Now

Energy performance has become front and center in the minds of homebuyers during recent years. The high cost of energy and parallel increases in utility bills have raised consumer demand for efficiency. Together with increases in building energy-code requirements, homeowners, builders and community developers are more frequently turning to closed-cell spray polyurethane foam (ccSPF) as an insulation and exterior material. The material has a higher R-value per inch than competing products, significantly reduces air and moisture infiltration to the building envelope and provides continuous coverage, thus providing labeled R-value without settling and without R-value degradation after installation—a significant problem with other insulation materials.

New research by Oak Ridge National Laboratories, highlight the effectiveness of ccSPF in substantially and consistently improving the energy performance of homes.

The application of ccSPF to improve energy performance, discussed in detail in this residential construction white paper, provides a dependable method to build homes that achieve the standards of many high-performance home programs, including the EPA's Energy Star for New Homes Program and the U.S. Green Building Council's (USGBC) LEED for Homes Program.

In addition to providing energy benefits, ccSPF provides unparalleled moisture performance, improved indoor air quality, is relatively easy to build with, and is effective in terms of first and life-cycle costs.

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An established track record of energy and thermal performance in homes, coupled with increasing energy-code requirements and a rise in consumer demand for energy-efficient homes will likely encourage homebuyers, homebuilders, architects and engineers to consider the use of ccSPF.

## 1. Energy Performance in Residential Construction

Homes account for 21% of the energy used in the United States each year (Department of Energy, 2006) and average \$1,767 in annual energy bills. Heating, cooling and hot water account for 50-70% of energy used in homes (Environmental Protection Agency—[www.energystar.gov](http://www.energystar.gov)).

According to the Department of Energy, prices for natural gas and electricity will only continue to rise (Department of Energy, 2007), driving new homebuyers to more carefully consider the energy performance of the homes they purchase. In addition, federal, state and local governments are beginning to focus efforts to conserve energy in the residential sector to improve national energy security and reduce our reliance on foreign oil. This will result in changes to building codes to increase the standard of energy performance. For example, Oregon recently proposed changes that will require all new homes built to be 15% more efficiently than the minimum standards of the 2004 International Building Code. New voluntary incentive-based initiatives from the Department of Energy are encouraging homes to be built with HERS (Home Energy Rating System) scores of 70 or better, significantly higher than the Environmental Protection Agency's Energy Star for New Homes requirements.

Joe Lstiburek, Ph.D., principal of Building Science Consulting in Westford, Mass. likens the challenge of saving energy in a building to filling a leaky bucket with water. To continue keeping the bucket full, you can continually search for more sources of water (alternate or renewable energy sources). Or, you can first try to plug holes in the bucket (energy conservation).

Plugging the holes isn't always as simple as it sounds. It can be difficult for builders to consistently improve the energy performance of the homes they build. High industry

turnover rates and lack of experienced labor often mean errors in installation, resulting in R-value performance far less than product labels state. Technology in homebuilding has advanced significantly in recent years, but stick- and site-built construction is surprisingly old school in practice, involving many disparate products assembled by different trades to form one whole system. Quality installation of air barriers, water-management systems and insulation materials is too often sacrificed for speed and cost. This short-term savings impacts the builder's long-term profit margin by creating an increase in callbacks and warranty issues, as well as detrimentally impacting the homeowner with higher utility bills and decreased comfort.

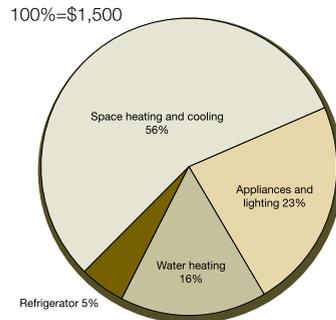
The complicated interplay between building systems, trade contractor installation performance and increasing energy-performance requirements suggests that homebuyers, homebuilders, architects and engineers who seek cutting-edge performance should consider products that provide the critical combination of forgiving flexibility and performance.

## 2. New Research—Designed vs. Installed R-value and Cathedralized Attics

Air leakage in the building envelope is one of the most challenging issues in energy performance, and can account for as much as 20-30% of energy losses in a home (NAHB, 2007). Wall systems account for significant energy loss and are the most complicated component of the building envelope to insulate, seal and control moisture because of the number of perforations and mechanical system components housed within walls. Because of the significance of wall systems in overall energy performance and the challenges in building and insulating high-performance wall systems, Oak Ridge National Laboratory (ORNL) conducted a study to determine the actual R-value performance of insulation products when installed, as compared to the labeled R-values. The results were striking. Fiberglass batt insulation labeled at an R-value of 19, showed an R-value of 17 when perfectly installed. When installed as commonly found in walls, the R-value was 13.7 (ORNL 1998).

## The Importance of Insulation

**Insulation helps create a living space that is comfortable, healthy and energy efficient**



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### Air Flow

- Keep unconditioned air from leaking in
- Keep conditioned air from leaking out
- Prevent drafts within the structure

“Today, it is estimated that in residential and small commercial buildings, over 50% of the energy loss is associated with heat transfer and air leakage through building envelope components.”

ORNL <sup>1</sup>

### Heat Flow

- Keep heat in during winter
- Keep heat out during summer
- Maintain uniform temperature

“Heating and cooling (space conditioning) account for 50 – 70% of the energy used in the average American home.”

DOE

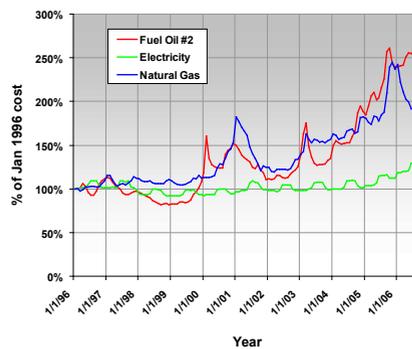
### Water Flow

- Bulk
- Air
- Vapor

“Of all environmental conditions, moisture poses the biggest threat to structural integrity and durability, accounting for up to 89% of damage in building envelopes.”

M.T. Bomberg <sup>3</sup>

Relative Utility Costs, 1996-2006



1. Oak Ridge National Labs  
[www.eere.energy.gov/consumer/tips/air\\_leaks.html](http://www.eere.energy.gov/consumer/tips/air_leaks.html)  
 2. Department of Energy [www.energystar.gov](http://www.energystar.gov)  
 3. Building Envelope and Environmental Control: Part 1 - Heat, Air and Moisture Interactions by M.T. Bomberg and W.C. Brown, Originally published in "Construction Canada" 35(1) 1993, p. 15-18  
 4. Source: U.S. Department of Labor, Bureau of Labor Statistics, Average Price Data [www.bls.gov](http://www.bls.gov)

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The work done by ORNL confirms findings from nearly three decades ago by fiberglass-insulation manufacturers and highlights the issues in insulation installation that can degrade R-value performance.

In addition to the studies regarding designed vs. installed R-value, ORNL performed tests to evaluate the performance of different insulation systems in providing extremely high

levels of insulation performance in attics now required by code in some areas of the U.S. (i.e. Wisconsin). The 2005 study tested loose-fill fiberglass, as well as low-density and medium-density spray polyurethane foam (SPF) insulations. The SPF systems significantly outperformed the loose-fill fiberglass, maintaining 74% and 83% of labeled R-value during cold conditions compared to 46% for the fiberglass

system. During hot conditions, SPF systems maintained 61% and 67% of labeled R-value compared to 51% for the fiberglass system. This information is particularly important when ducts or HVAC equipment are installed in attic spaces, as extremes in temperature can cause the use of significantly more energy to heat and cool the home.

Furthermore, ccSPF can be used to create unvented, conditioned attics, which prevent air leakage—a common problem in many homes. Often, holes created by air-conditioning equipment, exhaust fans, ductwork, recessed lighting and other such penetrations allow for the movement of air between the attic and living spaces.

According to Brad Oberg, CTO with IBACOS, Inc., a building science research and consulting company in Pittsburgh, “The use of spray foam to create a conditioned attic using a cathedralized attic strategy is an excellent insulation option. You get a much more thorough and uniform application with spray foam than with other netted or supported insulation systems.”

Plus, sealing soffits with ccSPF to create an unvented attic reinforces them against failure and prevents wind-driven rain from entry. This also prevents undesirable internal pressurization of the roof during high winds, and the sealant acts as a back-up waterproofing layer to further minimize any potential water leakage.

### 3. Energy Performance— Other Issues

Clearly, the thermal performance of wall systems is one of the most significant issues in energy performance as related to insulation selection and installation. However, other interrelated issues also must be addressed when building high-efficiency homes.

- Insulation, working together with the roof, wall and foundation assemblies (as well as the related sub-elements of each assembly), forms the building envelope
- Among other functions, the building envelope must:
  - Keep wind and unconditioned air out
  - Keep the conditioned air in
  - Prevent drafts
- Air movement (into and out of the house) has many detrimental effects:
  - Moisture within air impacts the long-term performance and structural integrity of the building
  - Introduction and distribution of pollutants and microbes
  - Thermal heat transfer <sup>1</sup>



- To address these concerns, many building scientists have concluded that houses should be as tight and seamless as possible <sup>2</sup>
- The American Lung Association also recommends that homes need to be as tight as practical <sup>3</sup>
- Random natural infiltration should be minimized and controlled mechanical ventilation should be employed <sup>4</sup>

1. Joseph Lstiburek, Ph.D., P. Eng., Building Science Corporation  
 2. Arnie Katz, Director, Affordable Housing, Senior Building Science Consultant  
[www.advancedenergy.org/buildings/about/specialists/arnie\\_katz.html](http://www.advancedenergy.org/buildings/about/specialists/arnie_katz.html)  
 3. American Lung Association  
[www.healthhouse.org/build/TopTenQuestionsbooklet.pdf](http://www.healthhouse.org/build/TopTenQuestionsbooklet.pdf)  
 4. [www.buildingscience.com](http://www.buildingscience.com)

#### Air Leakage:

According to the Air Barrier Association of America, a “typical 2,500-square-foot home has more than a half mile of cracks and crevices.” Unsealed, about a third of the air leakage in a home occurs through the floors, walls and ceilings.

Air flows most readily through gaps in drywall and sheathing, such as those created during installation of doors, windows and rim and framing joists, as well as wall perforations around electrical outlets and plumbing. Conventional insulation systems such as fiberglass batt require separate air barriers or additional sealing to perform at labeled R-values in real walls, allowing for an additional margin for error in insulation installation and performance. Using ccSPF, however, reduces air leakage, in addition to providing insulation.

**“With an average 8 mph wind, air movement through fibrous insulation can result in a loss of R-value up to 30%.”**

—DuPont, 2007.

## Moisture Control:

Water and moisture in the building envelope is the single greatest threat to building durability in residential construction. In addition to causing building-durability issues, moisture can create ideal conditions for mold growth, which can dramatically impact occupant health. Occupant health issues can range from allergic reactions to asthmatic episodes and respiratory issues. The proper application of ccSPF can be an excellent part of the home's water-management system, and is the only insulation system with an integral vapor retarder. Because of this, applying the proper thickness of ccSPF (typically 2 inches depending on climate zone and foam specifications) avoids unwanted condensation in the building shell. No other single product offers this inherent protection from moisture-related issues. It is also worth noting that ccSPF is considered an acceptable "flood-resistant material" by FEMA because of its ability to be exposed to water for significant periods of time without sustaining damage.

**“At 1 perm, closed-cell SPF is semi-impermeable, enabling it to allow for controlled breathing and drying. SPF uniformity and consistency enables it to resist passage of vapor equally well in all directions.**

— David Frame, *Journal of Light Construction*

Many insulation systems require an additional vapor retarder according to code to minimize moisture condensation within the building envelope. Insulations such as fiberglass (without facing), cellulose and open-cell SPF are vapor permeable, and require a vapor retarder in IECC climate Zones 5 and above and Zone 4 in Washington, Oregon and California (2006 International Energy Conservation Code). If the vapor retarder is properly installed with no perforations, seams or gaps, moisture movement by diffusion and convection flow can be prevented. However, vapor permeable insulations allow free movement of water vapor and, alone, do not serve as a vapor retarder. Because of this, if a fibrous insulation system is used with a separate vapor retarder and any gap or puncture occurs during installation, moisture will flow through the enclosure

and may create condensation issues. Closed-cell foam, when sprayed to a thickness of about 2 inches, will provide a vapor retarder of 1 perm or less, meeting IBC and IRC building code requirements for vapor retarders.

**“Controlling rain and ground water are the most important factors in the design and construction of durable buildings and for the control of mold.”**

— Joe Lstiburek, Building Science Consulting, Water Management White Paper (BSC, 2001)

## 4. Closed-Cell Spray Foam: What It Is and How It's Used

Closed-cell spray polyurethane foam (ccSPF), also known as medium-density spray foam, can be used as cavity insulation and as an exterior wall and roof material. The material has applications in all climate zones. Blowing agents include Honeywell's Enovate HFC-245fa, which has U.S. Environmental Protection Agency SNAP (Significant New Alternatives Policy) approval as a replacement for earlier generations of ozone-depleting products.

Another product used in U.S. residential construction is open-cell SPF, or ocSPF. While closed-cell SPF weighs about 2 pounds per cubic foot, the open-cell product weighs only about ½-pound per cubic foot of applied material. The term "open cell" refers to the fact that the tiny bubbles that make up the foam fill with air upon installation. The foam feels softer than ccSPF, which has closed cells filled with the blowing agent.

Both ocSPF and ccSPF expand upon application to fill voids and can create an air seal; both materials also adhere to common construction surfaces. But ccSPF provides higher insulation capabilities (R-values of around 6.2 or greater per inch) than open-cell materials (about 3.5 per inch). The ccSPF can also act as an air barrier at thicknesses of 1 inch or greater, and as a vapor retarder at 2 inches or more. The open-cell products, on the other hand, have a higher vapor permeability. Closed-cell materials also tend to cost slightly more by volume, because they pack more material into the same space.

For exterior roofing applications, an SPF product of up to 3 pounds per cubic foot is typically employed. For unvented roof

## 5. Benefits of ccSPF: Thermal Performance

**Creating a quality high-performance building envelope is the first step in creating an efficient home. Says Brad Oberg, CTO of IBACOS, Pittsburgh, “The energy benefit of a well insulated envelope is that your mechanical system doesn’t have to deal with the heat gain or loss that would occur in a lesser quality envelope, which makes it possible to downsize the mechanical system. You have to start with conservation first—and that starts with controlling the envelope. Properly applied spray foam insulation can help considerably.”**

assemblies, ccSPF insulation has been shown to be highly effective when applied under a roof deck. In addition, some faux-wood trims are made with very dense polyurethane foams with densities up to 40 pounds per cubic foot.

Although open-cell spray foams have a slight advantage over ccSPF in acoustic performance, and the installed cost of ccSPF is incrementally (10-20%) lower than ccSPF, ccSPF is not advised and often not allowed for exterior applications and below-grade or flood-prone situations because the product will absorb water, defeating its insulating abilities. Where builders face small framing sizes and need the most R-value possible per inch, ccSPF is an effective solution.

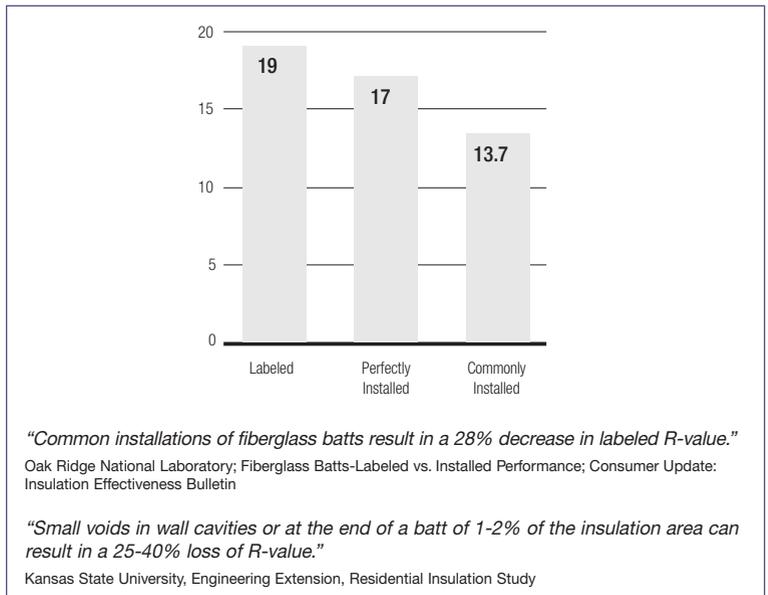
### Who Gains by Using ccSPF

ccSPF CAPABILITY	Home Design Benefit	Home Builder Benefit	Code Benefits	Climate Benefits
Impermeable to air	Controls airflow	Combined insulation and air barrier	Improves wall and roof performance	Warm climate: Keeps humid air out
Expands and adheres	Creates an air seal, reduces leakage	Fills voids; ensures contact with studs and walls for better insulation	Improves wall and roof performance	Cold climate: Keeps humid air away from back of roof sheathing
High R-value	Compact roof and wall assemblies	Improves insulation for small stud sizes	Highest R-value per inch	All climates: Reduces HVAC energy required
Resists water vapor	Reduces condensation problems	Vapor retarder not needed	Prevents condensation damage	Cold climate: Provides first condensing plane
Impermeable to water	Flood resistant	Acts as waterproofing and secondary rainwater barrier	Limits flood damage	All climates: Controls rain leakage

Source: Building Science Consulting

Above and beyond all other benefits, the superior and consistent thermal performance offered by ccSPF is the most substantial advantage related to energy performance. The material resists heat movement in all directions, avoids thermal bridging and provides reliable performance under varying conditions.

### Thermal Performance



Closed-cell SPF offers more consistent thermal performance, without the significant variation in R-value found in other insulation systems, such as fiberglass batt insulation. Because ccSPF is sprayed in and rapidly expands to fit the space being insulated, it eliminates gaps and cracks left during the installation of other materials. The material isn’t subject to the same installation issues as other products—because of its rigidity, there’s no risk of compressing, wrinkling or stuffing the insulation inappropriately, thus degrading R-value performance.

Conventional insulations have limited R-value because they use still air as an insulator. Closed-cell spray polyurethane foam (ccSPF) insulation has superior thermal performance because it replaces still air with less thermally conductive gases, such as Honeywell Enovate® blowing agent.

A recent study conducted by the Spray Polyurethane Foam Alliance entitled “Effects of Air Infiltration and Mean Temperature on the Thermal Performance of Insulated

Frame Wall Assemblies” evaluated thermal conductivity of insulation materials, real-world effects of air infiltration and mean temperature. A Wall Performance Index (WPI) was calculated for the insulation systems tests and created a rating to compare actual versus expected thermal performance. The WPI for closed-cell spray foam insulated wall systems in the study was significantly higher than that of the fiberglass and ocSPF walls, and the ccSPF wall performed consistently at or above expected values.

Schumacher also notes that because ccSPF is air impermeable and adheres well to construction surfaces, as it expands to fill voids it creates a superior air seal for the building envelope.

Increasing the home’s energy efficiency isn’t the only benefit of ccSPF’s air-sealing properties. Air sealing provided by ccSPF also reduces the amount of pollutants that enter the home, reduces sound transmission and increases occupant comfort by reducing drafts and creating more uniform temperatures throughout the home.

## 6. Benefits of ccSPF: Airtightness

Closed-cell SPF, because of its unique cell structure and tenacious ability to bond to other construction materials, provides an impermeable air barrier for walls, floors and ceilings. Tested as a material, closed-cell spray foam is four times less permable than open-cell spray foam (tested with building paper) and 100 times less permeable than cellulose insulation. To maintain indoor air quality, minimum ventilation requirements are prescribed by building codes (ASHRAE 62.x) -and to achieve adequate ventilation while conserving energy, an energy recovery ventilation system is suggested.

## 7. Benefits of ccSPF: Water and Moisture Control

Just as significant as thermal performance and air infiltration prevention is ccSPF’s ability to help prevent water and moisture from permeating the home by creating an integral vapor retarder. Fibrous insulations allow free movement of water vapor and, alone, do not serve as a vapor retarder. Closed-cell foam, when sprayed to a thickness of about 2 inches, will provide a vapor retarder of 1 perm or less, meeting IBC and IRC building code requirements for vapor retarders.

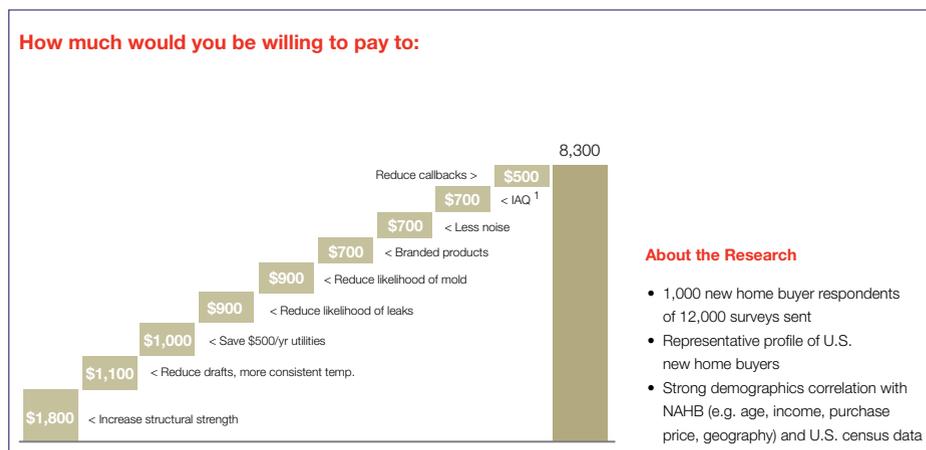
“In cold climates ccSPF prevents warm, humid indoor air from reaching the back [underside] of roof sheathing, where it can condense,” explains Schumacher. “In warm climates

it prevents humid outside air that enters the roof due to natural and/or controlled ventilation from reaching the back of the roof sheathing, which can be cooled below the air temperature by night sky radiation”—in other words, he explains, “the effect that causes dew.”

Closed-cell spray foam helps repel rainwater, too. “Closed-cell spray foam has negligible water permeability, minimal water absorption and excellent adhesion, allowing it to act as a secondary rainwater barrier to limit damage when primary roof assembly rainwater-control membranes leak,” says Schumacher.

“The technology has a very high structural adhesive property,” concurs David O. Prevatt, Assistant Professor

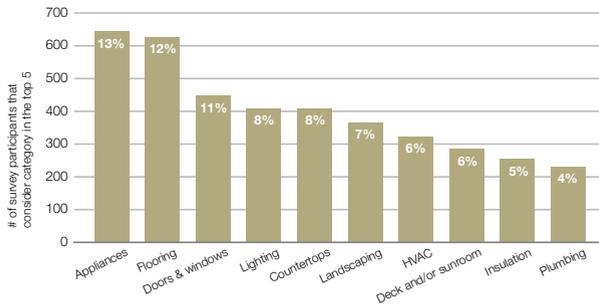
### Home Buyer Needs Analysis



“Closed-cell spray foam acts as an air barrier (at 1 inch or 25 mm minimum thickness) and vapor retarder (at 2 inches or 50 mm minimum thickness) and therefore does not need an additional vapor retarder in cold climates,” states Christopher J. Schumacher, a principal with Building Science Consulting, Westford, Mass.

### Top categories for upgrade dollars

Appliances, flooring, doors & windows, lighting and countertops were the most common categories for upgrade dollars. Insulation was listed as the ninth most likely category for upgrade dollars.

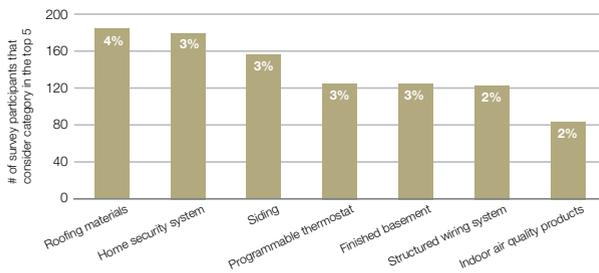


Insulation upgrades make the "top-ten" list for options spending

> 50% of the participants were highly satisfied with the upgrade options that they purchased

Homes > \$500,000: top upgrade dollar spending was for countertops, flooring and doors & windows.

### Categories with lower spending upgrade dollars



"The foam insulation resists the diffusion of water vapor so that the amount of water vapor is reduced as it moves through the thickness of the foam. By the time the water vapor reaches the back of the roof sheathing, there is not enough left to cause condensation problems," he says.

Helping to keep buildings dry during a flood is yet another ccSPF water-related benefit. Along these lines, Lstiburek classifies ccSPF as an integral part of flood-resistant home building. "If an insulation system like closed-cell polyurethane spray foam is used, it will not be damaged and will protect the wood [that it is insulating] during a flood," he explains. "Afterwards, just let the building dry with a dehumidifier, then

powerwash it, and you're done." In summary, he adds, "It's a powerful technology: It has extremely low water absorption and very low vapor permeability, which are good attributes for a roof."

in the Department of Civil and Coastal Engineering at the University of Florida. "Everywhere there are joints and cracks, the [spray foam] seals and prevents the entry of water."

According to Building Science Consulting's *Unvented Roof Assemblies for All Climates*, in cases where the primary roof does leak, the ccSPF application works to contain the damage and keep it from spreading throughout the assembly and to the interior finishes, thus making it easier to identify the source of the leakage problem.

For low-slope roofing, ccSPF, by itself, can actually perform as a primary water barrier due to its high adhesion and closed-cell characteristics. It keeps away mold and mildew and is the only FEMA-approved cavity insulation for homes built in flood zones.

With regards to vapor diffusion, analysis of the product's performance has also shown it to act as a "throttle" to control the rate of diffusion, according to Schumacher.

## 8. Achieving Energy Star's Thermal Bypass Checklist with ccSPF

The Environmental Protection Agency's Energy Star Qualified Homes Program, which requires builders to build homes to a high level of energy performance, specifies activities to ensure that thermal barriers are thorough and complete through their "Thermal bypass Checklist." The checklist is a thorough set of construction details where thermal bypass often occurs due to missing air barriers or gaps between the air barrier and insulation.

The checklist is a program requirement, and addressing these issues is critical to achieving Energy Star levels of

performance. Closed-cell SPF creates a quick and effective way for builders to achieve the items on the checklist by:

- Creating an overall air barrier and thermal barrier alignment, in which the insulation and air barrier must be in full contact.
- Creating an efficient method to insulate walls adjoining exterior walls and unconditioned spaces such as the walls behind the shower/tub and fireplace, insulated attic slopes/walls and knee walls.
- Creating an insulation installation that maintains permanent contact with the subfloor above in ceiling cavities.
- Fully sealing shafts such as duct, piping and flue shafts.
- Sealing attic and ceiling penetrations.
- Sealing in common walls between units.

## 9. White Paper Action Plan: ccSPF for Better Homes

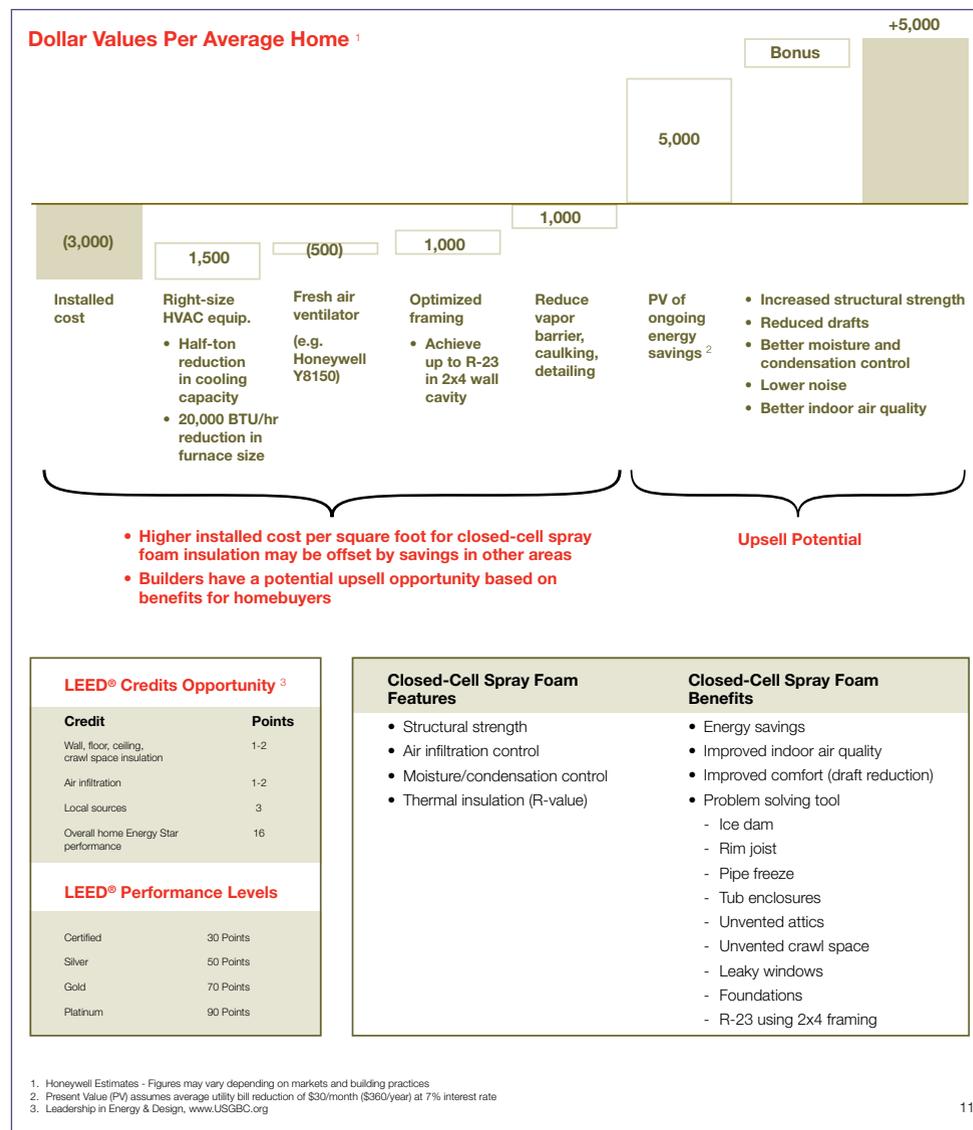
Based on the reporting and observations made in this white paper, we recommend the following “action plan” for homebuilders, designers and building authorities, as well as for homeowners. These recommendations specifically address growing concerns about energy performance in homes:

**1. Continue to study ccSPF insulation.** It is clear that closed-cell spray polyurethane foam (ccSPF) provides significant advantages in general, but also specifically in energy performance. In addition to improved thermal performance, ccSPF increases moisture and water resistance and building airtightness. The advantages should be studied further to improve homebuilding techniques and built-home performance.

**2. Expand education on ccSPF.** The properties and benefits of construction assemblies using ccSPF are not common knowledge among all builders and designers. Continuing education on the advantages and opportunities of presented by ccSPF insulation should be expanded.

**3. Consolidate and publish studies on ccSPF performance.** While this white paper makes an informal attempt to assemble various sources of data on ccSPF insulation, roofing systems and walls/enclosures, it is far from complete.

### Cost Trade-offs of Using ccSPF



We encourage trade groups, academic think-tanks and professional communities to publish findings on ccSPF in the field and in the lab.

**4. Promote the use of ccSPF insulation in wall and roof assemblies.** Because of the benefits to sustainability, building durability and homeowner comfort, homebuilders, homebuyers, developers and designers should consider the use of ccSPF where appropriate and suitable.

**5. Create awareness among code officials and enclosure experts.** The benefits of ccSPF for building occupants, property value and enclosure performance are well documented. In general, it serves as the basis for energy-efficient walls and roofs with good air-quality performance. As these qualities serve the interests of code officials and the jurisdictions they serve, we encourage more awareness among those key policy makers.

## Comparing Insulation Products and Features

Feature and benefit	Insulation product type				
	Closed-cell SPF	Open-cell SPF	Cellulose	Fiberglass batt	Fiberglass loose fill
R-value per inch Reduces wall thickness and framing costs	6.2	3.6	4.0	3.7	3.2
Air barrier material Increases energy savings, reduces drafts, improves air quality	Yes	No (1)	No	No	No
Expands to fit Provides labeled R-value; eliminates settling	Yes	Yes	No	No	No
Low water-vapor transmission Provides moisture control	Yes	No	No	No (2)	No
Low water absorption Qualifies as FEMA-approved flood-resistant material	Yes	No (3)	No	No	No
High strength and stiffness Improves structural integrity, durability and safety	Yes	No	No	No	No
No measurable formaldehyde Improves indoor air quality	Yes	Yes	Yes	No	Yes

1. Not considered an air barrier material per Air Barrier Association of America.
2. Will qualify as an integral vapor retarder when facings are attached.
3. Closed-cell absorbs minimal amounts of water (from 0 to a maximum of 4%, depending on manufacturer). Open-cell foams absorb in excess of 30% by volume.

## NOTES AND SOURCES

1. Air Barrier Association of America.
2. Qualifies as integral vapor retarder when facings are attached.
3. Open-cell SPF absorbs more than 30% water by volume; closed-cell SPF (ccSPF) absorb between 0 and 4% water by volume.

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## Presented by Honeywell

Honeywell International is a \$34 billion diversified technology and manufacturing leader, serving customers worldwide with aerospace products and services; control technologies for buildings, homes and industry; automotive products; turbochargers; and specialty materials. Based in Morris Township, N.J., Honeywell's shares are traded on the New York, London, and Chicago Stock Exchanges. It is one of the 30 stocks that make up the Dow Jones Industrial Average and is also a component of the Standard & Poor's 500 Index.

Specifically, Honeywell is a leading innovator in high-performance foam insulation blowing agent technology. Honeywell Enovate® blowing agent, a hydrofluorocarbon (HFC), is a non-flammable zero-ozone-depleting liquid that allows insulating foam to expand. Moreover, it helps provide many of the foam's key performance characteristics. Honeywell Enovate has been used for years to help appliances achieve ENERGY STAR® ratings and is rapidly being adopted to insulate homes, especially walls, basements and attics. This energy-efficient technology also is now being used for novel applications such as solar water heaters in China and hurricane-resistant roofing for commercial buildings such as the Louisiana Superdome.

Honeywell continues to innovate through its ongoing materials development programs, which include a low global warming potential (GWP) solution for one-component foam used to seal around windows and doors in Europe.

For additional information, please visit [www.honeywell.com/enovate](http://www.honeywell.com/enovate).

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