Remodeling for Efficiency

Whether inspired by a desire to update the floor plan, gain more space, or eliminate cold, drafty spots, remodeling is a chance to improve energy efficiency

When homeowners think of remodeling projects that will improve the energy efficiency and comfort of their houses, they're likely to think of replacing their windows. It's a good impulse; old single-pane windows can be leaky, cold, and prone to condensation in winter. And with about 80% of U.S. housing stock built before 1980, there is plenty of room for improvement.

However, to maximize the performance of any efficiency upgrade, including new windows, it's important to look at the entire house and prioritize efficiency improvements based on how they affect the entire system. There are two benefits to tackling the home with this system approach: First, homeowners get the most for their remodeling dollar. Second, the comfort and energy-saving expectations from windows and other big-ticket items actually happen, so homeowners are satisfied customers.

Have a plan

Don't try to improve the energy performance of a house haphazardly. Ignoring how house components affect each other leads to unintended consequences. For example, starting by replacing an HVAC system with more-efficient components is admirable. But if you then tighten the building envelope by air-sealing and follow with a thick blanket of added insulation, this new HVAC system could be oversize, causing it to short cycle and function at less than its rated efficiency. Also, it won't remove humidity in the summer and will lead to wider temperature swings during the heating season. The end result is an unhappy homeowner.

Almost any remodeling project offers a chance to incorporate energy-efficiency improvements that might be considered too invasive to tackle otherwise. However, the least invasive energy improvement, air-sealing, is the one that should be done first, and it offers great return for a modest cost.

Start with air-sealing

Air moves freely through fibrous insulation such as cellulose, fiberglass, and rock wool, creating convention currents that degrade their performance. Consequently, the starting point for any efficiency improvement plan is finding and sealing the large and small holes in a house's envelope that let conditioned air out of the house and unconditioned air into the house. In a typical house,

SPECS

BEDROOMS: 3

BATHROOMS: 2½

SIZE: 2800 sq. ft.

COMPLETED: 2011

LOCATION: Media, Pa.

ARCHITECT: Period Architecture Ltd.

CASE STUDY:

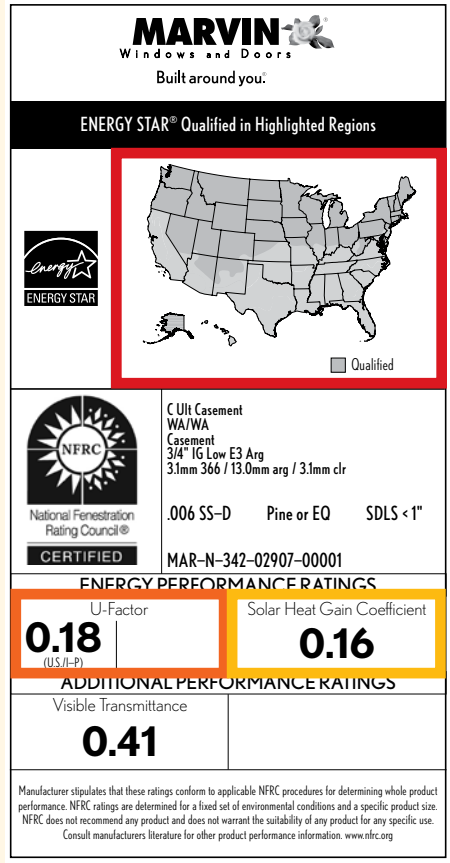
UNCOVERING A PERIOD GEM

A remodel isn't always about bringing the latest styles and amenities to a house; sometimes it's about undoing the mistakes of past renovations and restoring a home to its original glory. When Jeffrey Dolan, a co-founder of Period Architecture, was brought in to assess this 1776 farmhouse built by a Pennsylvania farmer, it took experience and imagination to see past the stucco exterior, vinyl siding, shag carpeting, sheet-good paneling, vinyl windows, and drywall. Removing the aggregation of more than 200 years of changing architectural tastes revealed thick fieldstone walls, plaster finishes, hand-hewn chestnut beams, and white-oak flooring. Dolan and his preservation crew ordered custom-sized Marvin windows to fit the varied openings and reuse the original casings. The 6-over-6 wood windows restored the original look, and the dual-pane glass added insulation and air-sealing for comfort.

KNOW THE WINDOW RATING LABEL

Window rating labels list performance ratings such as U-factor, solar heat-gain coefficient, and visible transmittance. Evaluate these ratings based on the performance need for the project. U-factor indicates how well the window will insulate. A lower number indicates better insulating properties. Make ENERGY STAR® qualification your starting point (see chart). The solar heat-gain coefficient (SHGC) indicates how much of the sun's warmth will pass through the window; the coefficient is reported between 0 and 1, with lower numbers indicating less heat gain. Visible transmittance (VT) is the amount of natural light that can come through the window. It is also measured between 0 and 1, with a higher value indicating more daylighting.

ENERGY STAR Standards		
Climate Zone	**U-factor***	**SHGC***
Northern	≤ 0.27	any
North-central	≤ 0.30	≤ 0.40
South-central	≤ 0.30	≤ 0.25
Southern	≤ 0.40	≤ 0.25
*Only U-factor and SHGC determine ENERGY STAR qualification		



there are literally dozens of these pathways connecting indoor and outdoor air.

Before plugging up these holes, you'll have to identify the surface to use as the air barrier. It's an air-impermeable layer that stops air movement between conditioned and unconditioned spaces. The air barrier must also be continuous; if you were to look at the house in cross section, it should be possible to draw a pencil line along the air barrier without lifting the pencil point off the paper. For above-ground portions of the house, the air barrier is either the drywall or the sheathing. In an existing house, drywall is typically the air barrier unless the house is being resided and the sheathing exposed.

The materials required for air-sealing are easy to find and relatively inexpensive. If you do the air-sealing work yourself, the payback is fairly immediate. Basic supplies include canned spray foam, caulk, rigid insulation, and, perhaps, some plywood and metal flashing. Seal small holes and cracks with a good-quality caulk. It should be an elastomeric sealant to accommodate seasonal material movement. Tooling sealants and caulks so they bridge the two surfaces with an hourglass shape helps accommodate movement. Acoustical sealant is excellent for air-sealing because it doesn't harden; rather, it skims over and remains pliable. For sealing gaps larger than ¼ in., canned spray foam is a good option.

Flat ceilings are straightforward

The first and most obvious source of air movement is the attic access. (A quick health note: if the attic is insulated with vermiculite, don't disturb the insulation. You'll need to contact an asbestos-remediation contractor before doing work in the attic.) Whether it's a scuttle hatch or pull-down stairs, it needs an insulated cap that provides at least code-minimum R-value and weatherstripping between the cap and the framing material it rests on. Premade options include manufactured caps such as those by Battic Door (batticdoor.com) or ESS Energy Products (essnrg.com), but site-made rigid foam and plywood versions will do the trick as well.

With this hole addressed, turn your attention to the dozens of smaller penetrations and gaps in the drywall barrier. Before entering the attic, take a good look at the ceiling from below, and take note of the locations of light fixtures, interior walls, HVAC registers, chimneys, bathroom fans, range hoods, and dropped soffits so that you'll know where to look for likely leaks.

If you begin at one end of the attic, the first place to look is the joist along the gable end. If the gable wall is balloon-framed (where gable-end studs run from the floor below to the rafter), it can be a conduit for moving air between the attic and the living space below. At the ceiling level, these stud bays should have wood or rigid-foam blocking sealed to the framing and the wall sheathing.

Chimneys require air-sealing, as there's a chase around them running from the basement to the attic. The chase keeps flammable materials away from the chimney, so anything touching the chimney must be nonflammable. Mineral-wool insulation can be tucked in the gap around a masonry chimney, and L-shaped metal flashing (a piece of sheet metal or a piece of drip edge) can bridge the gap between the chimney and

SPECS

BEDROOMS: 3 upstairs, 1 in basement (before); 4 upstairs (after)

BATHROOMS: 1½ (before); 2½ (after)

SIZE: 1980 sq. ft. (before); 2800 sq. ft. (after)

COMPLETED: 2013

LOCATION: Stowe, Vt.

DESIGNERS: Andrea and Brian Hamor

BUILDER: Skyline Building Co., Richmond, Vt.

CASE STUDY:

A FACELIFT FOR AN OLD CAPE

Architect Brian Hamor and his wife sought a modest home in Stowe, Vt., that they could remodel into something that was uniquely theirs. The house they found had a great location but suffered from outdated finishes and a traditional Cape floor plan of small, closed-off rooms with tiny hallways and a tight kitchen. After moving in, they discovered that the outdated heating system and poor building envelope generated enormous heating bills—more than $6000 in the first six months. Their original plan to redesign the space with large windows and free-flowing interiors was expanded to include gutting the walls to the studs and meeting ENERGY STAR standards. While the wall framing was exposed, the 2x4 walls were insulated and air-sealed with spray foam. Hamor chose Integrity by Marvin windows to meet his efficiency goal and because the fiberglass frames would withstand the harsh northern climate with little maintenance. The multi-lite white windows and white clapboard siding honor the original Cape, but the taller windows and dormer "flares" inspired by Western agricultural buildings add a modern twist. When the remodel was done, the house was 1000 sq. ft. larger, yet winter heating bills had fallen by half.

Climate control. *Sunlight pours through the tall Integrity by Marvin windows and door in the south-facing mudroom, warming the porcelain tile during the day.*

the framing. Embed the flashing in a bead of sealant on the framing so that the other leg fits tightly to the masonry. Caulk the flashing to the chimney with RTV silicone or fire-block caulk, and add a few roofing nails through the flashing to the framing.

Metal chimneys require a slightly different approach. Start with two pieces of sheet metal that will allow you to bridge the hole around the pipe from each side. Cut a half circle in each piece of flashing to fit tightly around the pipe. Run a bead of high temperature sealant on the ceiling around the pipe to bed the outside edges of the flashing to the ceiling. Use RTV silicone or fire-block caulk to seal the circular edges of the flashing to the pipe. Insulation must be held back 2 in. from the pipe, so build a plywood insulation dam 2 in. from the pipe and higher than the final insulation level.

Next, move methodically from one joist bay to the next, thinking about your survey of the ceiling below. Wherever there is a light fixture, dropped soffit, HVAC register, or interior wall below, remove insulation and then plug any wiring, plumbing, HVAC penetrations, and drywall voids. Pay attention to dark batches of insulation, which are signs of an air leak. The insulation acts as a filter, as air flows through capturing dirt, dust, soot, and any other particulate matter.

Ceiling light fixtures are a source of leaks that require sealing. Junction boxes should be sealed to the drywall with caulk or spray foam, and all of the knockout tabs caulked or spray foamed. Be careful not to fill the inside of the box with spray foam, a code violation that creates the potential for a fire. (Some jurisdictions require that a fire-block-rated sealant or foam be used around boxes.) Recessed-can lights are notorious sources of air leaks. The remediation options depend on the existing lights. The best option is to replace the can lights with ceiling-mounted fixtures. If the can lights must stay, consider an LED retrofit kit, and seal the edge of the can to the edge of the drywall. Insulation-contact-rated cans have a thermal cutoff and

A WINDOW FOR EACH REMODEL

Marvin windows come in several installation styles to match the scope of a renovation. 1 New-construction windows attach to the sheathing with fasteners through nailing fins. This style is appropriate when residing the house or removing the siding around windows because of leaks through the original window flashing. 2 Replacement windows are good for improving energy-efficiency without disturbing the exterior casing or the interior trim. The frame-in-frame design is custom built to match precisely each existing window. 3 Marvin's tilt pac sash replacements are another option for double- and single-hung windows where the frames are sound but the project calls for updating drafty or damaged sashes.

can be air-sealed with a Tenmat enclosure taped to the drywall. Noninsulation contact cans should be replaced.

Along the top plates of walls is a critical place to look for air holes. Penetrations for pipes and wires are common and can be sealed with canned spray foam. Drywall joints are also problematic. When the partition walls run perpendicular to the joists, you'll have easy access for sealing the gap. For parallel partition walls, the drywall meets beneath 2x backing, so you'll have to seal the edges of the 2x to the drywall.

If there are dropped soffits in the living space—such as a bank of upper cabinets in a kitchen—look for drywall gaps, and fill them with pieces of rigid foam sealed to the ceiling joists. Finally, be sure bathroom exhaust fans and all duct boots are sealed to the drywall.

Sloped ceilings are more challenging

So far, we've been talking about houses with an open attic entirely above the conditioned living space. Kneewalls, such as in a Cape Cod–style home or an above-garage bonus room, change your air-sealing strategy. There should be some type of air barrier between the floor joists under the kneewall; otherwise, unconditioned air will flow through the joist bays under the entire room. Rigid-foam blocking spray-foamed in place works well. Also, add some type of encapsulation on the outside of the kneewall. Many contractors prefer rigid foam for its light weight and additional R-value. Access doors through the kneewall should be sealed and insulated like they were an attic scuttle, with weatherstripping around the perimeter and insulation applied to the back of the door.

Air-sealing the basement

With the attic sealed, it's time to turn attention to the basement or crawlspace. There are two approaches here: the air barrier can be established at the subfloor of the first floor, or along the basement walls and floor. If the basement is conditioned finished space, the air barrier must be at the basement walls and the concrete floor.

If the walls and the slab serve as the air barrier, start by sealing all obvious cracks in them with masonry-compatible sealant. Pay particular attention to the joint between the floor slab and walls. Other penetrations through the concrete or the rim joist—such as electrical lines, cable lines, and water pipes—also require sealing.

The intersection of concrete and framing at the rim joist is a critical air-sealing spot. Each component is a potential leak; between the concrete and the mudsill, the mudsill and the rim joist, the rim joist and the subfloor, and butt joints in the rim joist. Not only is this assembly a source of air leaks, but it's typically uninsulated. Contractors have developed a couple of different preferred strategies for sealing and insulating this space. One common method is to cover the rim joist between each floor-joist bay with a piece of 2-in.-thick polyisocyanurate or XPS (extruded polystyrene) rigid foam. These pieces should be cut loose to the space and spray-foamed in place on all four sides. One trick some contractors use is to cut the edges with a slight bevel facing the interior to help the foam lock them in place. With this strategy, it's necessary to caulk the mudsill.

The other method of sealing this tricky area is to use a two-part spray-foam kit and seal and insulate the entire area with one go. The foam should lap from the subfloor all the way onto the concrete. This approach

CASE STUDY:

AN OLD HOUSE GETS A MODERN ENVELOPE

When architect Steve Baczek started work on this 1850 Cape, the house lacked even minimal modern performance standards. In serious disrepair, it easily could have been designated as a teardown. Instead, it became the perfect model of an old-house renovation that meets modern performance standards while maintaining its original charm and period detail.

The team started by removing the house's additions, which were falling apart, leaving a living room and a dining room downstairs, and a bath and two bedrooms upstairs. These spaces were small, but Baczek could tweak the rooms' dimensions for better use because a new addition would house a new kitchen, family room, and master suite. Because the house is located within the town's historic district, a face-lift for the front of the house couldn't alter any of its original aesthetics. To stay within historic-district guidelines, Baczek kept the original dimensions for all the exterior siding and trim. He specified new windows from Marvin that met today's performance requirements and had historically correct 6-over-6 sash lites separated by ⅝-in.-wide muntins. All of the windows were installed in a sloped pan flashing, complete with an end dam to the interior.

SPECS

BEDROOMS: 3 (before); 3 (after)

BATHROOMS: 1 (before); 2½ (after)

SIZE: 1875 sq. ft. (before); 2762 sq. ft. (after)

COMPLETED: 2012

LOCATION: Wayland, Mass.

ARCHITECT: Steve Baczek

BUILDER: Michael Brussard

With the new addition, the above-grade walls were a puzzle of original timber framing and new framing modifications. The existing walls' interior was sprayed with 4 in. of closed-cell foam, which has an R-value of 6.5 per inch and helped to air-seal the board sheathing. The new addition's 2x6 walls were insulated with less expensive, open-cell spray foam (R-3.5 per in.) Because these walls were deeper, though, Baczek could spray more, get about the same performance as with the closed-cell foam on the thinner walls, and spend less. Spray foam provided the primary air-sealing strategy, and the airtight-drywall approach served as a redundant sealing technique, with the crew applying a bead of sealant at the plates and around the perimeter of all window and door openings before hanging the drywall.

The old and new portions of the roof were sealed as an unvented assembly so that the mechanical systems could be housed in conditioned space. The lack of vents made the roof simpler to build and gave the house a cleaner look. Similar to the wall assemblies, the old roof was insulated to R-40 with closed-cell foam, and the new roof was insulated to R-40 with open-cell foam.

LOW-E COATINGS CHANGE PERFORMANCE

Low-e windows rely on a thin, invisible, metallic coating to reflect light and control the amount of heat that passes through the glass. (The "e" stands for *emissivity*.) On a double-pane window, the metallic layer can be sprayed on any one of the four glass surfaces (each glass pieces has an inside and the outside surface). The location and type of coating applied to the glass controls how much heat is allowed into the house from the outside (solar heat gain) and how much heat from the inside is allowed to escape (U-factor). Choose the right low-e type for your energy-performance needs.

Glazing	Climate	Energy Performance
Low E1	Northern	Low U-factor High solar heat gain
Low E2	Northern North-central South-central	Low U-factor, Medium solar heat gain
Low E3	Northern North-central South-central Southern	Low U-factor Lower solar heat gain
Low ERS	Northern (limited to warm parts of the region) North-central South-central Southern	Superior U-factor Lower solar heat gain

can be a little fussy because there's a learning curve to using the spray gun, and the basement will probably have to be heated to raise the temperature to the optimal range recommended for two-part kits.

A bulkhead is a major infiltration path in the basement. Rather than trying to air-seal and insulate the bulkhead itself, the door at the bottom of the bulkhead stairs should be an exterior, weatherstripped, insulated door. Be sure to seal the framing to the concrete and the space between the door jamb and the framing.

If the subfloor is chosen as the air barrier, the sealing process is similar to that used in the attic. Follow plumbing, wiring, and duct runs to where they pass through the floor, and close the gaps with sealant or spray foam. One area to pay attention to is the space beneath a bathtub drain where the plumber may have cut a large hole in the subfloor. A good approach here is to piece rigid foam around pipes to cover the entire hole, gluing the pieces to each other, the subfloor, and the joists with spray foam. The door at the top of the stairs should be upgraded to a weatherstripped, exterior door. Apply sealant to all plywood joints. If there's a plank board subfloor instead of sheet material, either use the walls and slab as the air barrier, or insulate the subfloor with spray foam.

Wrap the house in more insulation

With the house air-sealed, you can wrap it with another layer of insulation. Beef up the insulation in the attic first, as it has the greatest impact on stopping heat loss. In most cases, the attic floor is insulated, and the most cost-effective strategy is to add insulation to the existing layer. That might mean adding unfaced fiberglass or mineral-wool batts perpendicular to the joists, or blown-in insulation on top of the batts. Blown-in loose-fill cellulose or chopped fiberglass are great, inexpensive ways to add R-value to the attic. The amount of insulation you apply should meet the current code, which varies by climate region. Whether you plan to apply layers of batts or piles of blown-in insulation, soffit vents have to be detailed to keep the attic properly ventilated. Soffit vents require a clear air pathway from the eave to the ridge vent. This is something best done during the air-sealing process. Installing rigid-foam blocking between the joists at the eave serves as an insulation dam so that the insulation doesn't spill over and fill the soffit. At the same time, inserting a baffle channel between the rafters or trusses creates an open airspace along the underside of the sheathing. Premade baffle channels are readily available at building-supply houses, or you can make them with scraps of rigid foam. Sealing the baffle to the joist blocking ensures that air can't leak into the insulation, degrading its performance.

If the walls are uninsulated, adding insulation is relatively straightforward. Blown-in insulation does a good job packing stud bays with insulation and is relatively noninvasive. Blown-in wall-cavity insulation is generally not a DIY project, as the blowers available for rent aren't powerful enough to dense-pack wall cavities, and over time the insulation will settle, leaving uninsulated voids at the top of walls.

Any residing project should consider the opportunity for exterior insulation. Rigid insulation on the outside of the house significantly increases R-value without sacrificing floor space or having to cut walls open. Because the insulation is outside the framing, it eliminates thermal bridging, raising the real-world R-value of the existing wall. When adding exterior insulation, it's important that R-values be appropriate to the climate, or condensation can occur and the sheathing be unable to dry to the outside.

Windows save energy and improve comfort

Windows are an important design element that can change the look of a house inside and outside. However, it's worth thinking about windows as holes in the walls where the thick wall insulation is removed in favor of a glass unit to let in light and fresh air. They are a potential weak spot for heat transfer and air infiltration, so it's important to choose windows with good insulating qualities and very low air-leakage rates.

Choosing the appropriate window not only reduces your energy use through insulation and airtightness, but it increases your comfort by eliminating cold spots and controlling heat gain from the sun.

An ENERGY STAR rating can be the starting point for window and door selection. It ensures that windows and doors meet a benchmark performance of insulation and how much solar heat passes through the glass. These specs are documented on the window in the NFRC label.

U-factor reports a window's insulating properties by measuring the flow of nonsolar heat through the window. You can think of it as the rate of conduction; the lower the U-factor, the less heat will flow through the window. The airspace between glass panes serves as insulation by interrupting the path of heat through the window. A single clear pane has a U-factor of 1.04, but a sealed double-pane unit has a U-factor of 0.5. Adding a third pane improves the U-factor to 0.3. Replacing the air with gas further improves the insulating value of the window. Manufacturers use argon or krypton gases because they reduce heat loss, as they are less conductive than air. Argon and krypton also reduce convective losses because the gases are heavier than air, reducing gas movement within the insulating space.

Depositing a virtually invisible metal or metal-oxide coating on the glass makes insulating windows dramatically more efficient. This coating is transparent to visible light, but it blocks long- and short-wave radiation by reflecting it. Known as a low-e (for low-emissivity) coating, it's common today even on low-cost windows. Depending on the nature of this thin coating and which window surface it is applied to, the coating can reflect heat back into the room to conserve it or filter sunlight to keep heat out. Using a coating on two different glass panes can fine-tune the amount of heat that's retained in each direction. In northern climates, an ENERGY STAR window generally has to have a U-factor of 0.27 or better. However, because winter solar heat gain can reduce the heating load, it's possible for windows in northern climates to trade some insulating performance for more solar heat gain. Placing these windows on the south side of the house enables the sun's energy to warm the house throughout the day.

The amount of the sun's heat a window lets through is the solar heat-gain coefficient (SHGC), which ranges from 0 to 1, where 1 is uninterrupted heat gain. A clear-glass, two-pane insulated window has an SHGC of greater than 0.50. A tri-pane window with low E3 on one glass face and low E1 on another will result in an SHGC of less than 0.25. ENERGY STAR requires lower SHGC the further south a home is located to reduce heat gain in regions where air-conditioning loads are a major portion of annual energy consumption.

Whether to choose new construction windows or replacement windows depends on the extent of the remodel. If windows are being resized, the house resided, or walls reframed, it'll be new construction windows; otherwise, replacement windows probably make more sense. In both cases, installation technique matters. It's critical that the gap between the window and the rough framing is air-sealed. Scraps of fiberglass insulation stuffed around the jamb won't do the trick.

The peel-and-stick membranes commonly used around the exterior of the windows are a starting place for air-sealing, but it's best to think of them as the drainage plane to keep water out. Best practices involve additional air-sealing from the interior side of the window. Apply a relatively thin bead of low-expanding spray-foam insulation that doesn't fill the depth of the stud/jamb and header cavities. At the bottom of the window, don't fill the outside edge of the cavity; any water that finds its way past the exterior flashing tape needs a place to collect and drain to the outside. That's why the nailing fin on the bottom of the window isn't covered with peel-and-stick membrane. The foam is a first layer of air-sealing, but there can be small leaks, perhaps around the shims, that only become obvious during a blower-door test. Follow the spray foam with a backer rod of a large enough diameter that it has to compress to fit in the opening. Then apply a high-quality sealant to bridge from the jambs to the framing; the backer rod helps create the hourglass shape that makes the sealant most resilient. Finally, use a vapor-permeable flashing tape (Pro Clima Unitape and Siga Fentrim IS 20 are two examples) sealed to the rough frame on one edge and the window jamb on the other edge. Don't forget about the trim reveal; hold the tape back far enough from inside edge of the jamb that it will be covered by the casing.

REMODELING OLDER HOMES

Updating older windows with energy-efficient ones should not be at the expense of the house's architectural integrity. From casing style to divided-lite patterns to mutin size, it's important to get the details right. Houses with historic designations or in historic districts may face particularly stringent guidelines governing the material and appearance of new windows. In less strict environments, replicating the existing style with aluminum-clad wood or pultruded fiberglass will maintain the proper aesthetic with a durable, low-maintenance material.

Approach remodeling with efficiency in mind

Air-sealing, insulation, and windows play a critical role in the energy efficiency and comfort of a home. Strategies in each of these efficiency categories can be carried out in minimally invasive ways, but it's important to think of the opportunities that remodeling projects present to integrate these strategies and products. When they're part of a larger project, different installation methods are possible, and often they result in greater efficiency gains and reduced installation costs.