A Practical Look at Deep-Energy Retrofits

BY MARTIN HOLLADAY

Cutting a home's energy use by 50% to 90% is a worthy goal, but the extreme costs keep it out of reach for many. We take a look at the most cost-effective alternatives.

If you pay any attention to building science, you have probably seen the term "deep-energy retrofit"—a phrase being thrown around with the colloquiality of "sustainability" and "green." Like the word "green," the term "deep-energy retrofit" is poorly defined and somewhat ambiguous. In most cases, though, "deep-energy retrofit" is used to describe remodeling projects designed to reduce a house's energy use by 50% to 90%.

Remodelers have been performing deep-energy retrofits—originally called "superinsulation retrofits"—since the 1980s (see "Retrofit Superinsulation," *FHB* #20 and online at FineHomebuilding.com). Most deep-energy retrofit projects are predominantly focused on reducing heating and cooling loads, not on the upgrade of appliances, lighting, or finish materials.

While a deep-energy retrofit yields a home that is more comfortable and healthful to live in, the cost of such renovation work can be astronomical, making this type of retrofit work impossible for many people in this country. Those of us who can't afford a deep-energy retrofit can still study the deep-energy approach, using it to shed light on more

An old house with a new shell. *This deep-energy retrofit in Somerville, Mass., received 4 in. of spray polyurethane foam on its exterior. (For more information, see the case study on p. 60.) However, not all energy upgrades have to be so elaborate.*

Photo this page: courtesy of Green Building Advisor.
Photo facing page: Charles Bickford.

Energy retrofits of all levels

Paul Eldrenkamp is a Massachusetts remodeler who has performed several deep-energy retrofits. When his clients balk at the high cost of a full retrofit, he sometimes advises them to work in phases. Although it is common to perform energy improvements over time as finances permit, it's also important to take advantage of upgrade opportunities even if they seem to fall out of sequence. For example, if you have to install new siding or roofing and you do so without installing thick rigid foam underneath, you may regret your short-sighted decision in time. Here's a general overview of the work to be done, the order in which it should be completed, and the practical alternatives to going deep.

ROOF INSULATION

Deep-energy retrofit

Many deep-energy retrofits call for insulating a roof to R-60, which can most easily be done by adding 4 in. of rigid polyisocyanurate foam on top of the roof deck and then filling each rafter bay with loose fill or batt insulation. Exterior foam sheathing has the added benefit of reducing thermal bridging through the rafters.

Practical approach

It's much less expensive to install cellulose on an attic floor than to install rigid foam and new roofing. Address air leakage before dragging a cellulose hose into the attic. Seal all ceiling leaks under the existing insulation (for example, at electrical and plumbing penetrations, at utility chases, and at the gaps between partition drywall and partition top plates). It's also important to be sure that there are no air leaks

Pile it on. *If adding rigid foam on top of the roof sheathing isn't an option, a less expensive option is blowing cellulose on an air-sealed attic floor. The more insulation, the better.*

PHASE

1. **Get an energy audit.** An auditor will evaluate your home and develop a list of energy-retrofit measures (see "All Homes Need an Energy Audit," *FHB* #200 and online at FineHomebuilding.com.)
2. **Perform air-sealing work,** using blower-door test results to direct you.
3. **Install a mechanical ventilation system** once you've tightened up the building envelope.
4. **Start insulating the home from the top,** because a lot of heat is lost through ceilings and roofs.
5. **Insulate the interior side of basement walls,** a relatively easy task because basement walls are accessible.
6. **Install dense-pack cellulose insulation** into any empty stud bays of above-grade walls. This work is affordable and cost-effective.
7. **Install thick rigid foam on the exterior** of the sheathing and new high-performance replacement windows.
8. **Finally, install a new heating system.** This should be done last, because the unit should be sized for your new high-performance home. If a new heating unit is installed earlier in the project, it's likely to be too big.

at the perimeter of the attic, where the ceiling air barrier meets the wall air barrier.

Performance comparison

While there is no upper limit on the R-value that can be achieved when installing foam on top of the roof sheathing, the maximum R-value of attic-floor insulation depends on the available height at the perimeter of the attic. Achieving R-60 requires about 16 in. of cellulose.

Cost comparison

Attics with easy access are easier and cheaper to retrofit than cluttered attics with lots of penetrations that need to be sealed. From a material standpoint, the practical approach is almost always more economical. For any given R-value, polyisocyanurate costs from three to five times as much as cellulose insulation. Needless to say, adding rigid foam on top of the roof sheathing includes significant expenses for roof demolition, new roof sheathing, and new roofing—costing between $3 and $5.80 per sq. ft.

BASEMENT INSULATION

Deep-energy retrofit

After addressing any moisture issues in the basement, many deep-energy retrofits call for basement walls to be insulated to R-20, requiring the addition of 4 in. of XPS insulation or about 3 in. of closed-cell spray polyurethane foam. The rim joists are also insulated with either spray foam or rigid foam.

The basement floor is insulated with 2 in. to 4 in. of XPS foam over the slab. A new subfloor is applied over the foam.

Practical approach

Adding insulation to the basement walls and rim joists is cost effective in all northern climates. However, the payback period for basement-floor insulation is much longer than for basement-wall and rim-joist insulation, so it's often eliminated in projects with a limited budget.

Performance comparison

Since the temperature of the soil under a below-grade slab is higher than the average outdoor-air temperature in winter, heat loss through a basement slab is much less than through a basement wall. In many homes, basement slabs are responsible for less than 1% of a home's total heat loss.

Stop the leaks. *If a full basement-insulation job isn't in the budget, attack the rim joist. Spray polyurethane foam works best, but a more affordable option is to seal rigid-foam panels in each joist bay with canned spray foam.*

practical and cost-effective measures to make any home tighter and more efficient.

How deep?

No standard-setting agency has established a legal definition of a deep-energy retrofit, but the term generally refers to retrofit measures that reduce a home's energy use by 50% to 90% below that of a code-minimum house—or, according to a more lenient definition, below preretrofit levels. Probably fewer than 100 homes in North America have completed deep-energy retrofits that conform to the strictest definition of the term.

A house that has undergone a deep-energy retrofit typically ends up with R-20 basement walls, R-40 above-grade walls, R-60 roofs, and U-0.20 windows. A typical airtightness goal, determined by a blower-door test, is 1.2 ACH (air changes per hour) at 50 pascals.

A deep-energy retrofit doesn't make sense in all climates, and not every home is a good candidate for the work. Cold-climate homes have higher energy bills than homes in a hot climate, so a cold-climate home is a better candidate than a home in a hot climate or a home that already has low energy bills. A house

Retrofit results

Cost: $140K
Annual savings: $2300

While planning a deep-energy retrofit of his 3000-sq.-ft. two-story duplex in Arlington, Mass., owner Alex Cheimets got a lucky break: He was eligible to participate in a pilot superinsulation program sponsored by the Massachusetts Department of Energy Resources and his local utility.

Location: Arlington, Mass.

Size: 3000 sq. ft. (duplex)

Renovation cost: $47 per sq. ft.; $140,000 total

Photos this page: left, Charles Bickford; right, courtesy of Green Building Advisor. Photo facing page: Daniel S. Morrison.

with a simple rectangular shape and a simple gable roof is easier and less expensive to retrofit than a house with complicated exterior elevations, bay windows, dormers, or a roof full of hips and valleys. Most of the deep-energy retrofits include the installation of a new layer of exterior insulation. Intricate architectural details add to the difficulty of such retrofit work, driving up costs. Homes with simple exterior trim and uncomplicated cornice details are much easier to work on than Victorian homes with gingerbread trim. Because many deep-energy retrofits require existing roofing and siding to be replaced, the best candidates for deep-energy retrofit work are houses that are in need of new roofing and siding.

The payback

Homeowners who undertake deep-energy retrofits are usually motivated by environmental or energy-security concerns rather than a desire to save money on their energy bills. These jobs are so expensive—in the range of $50,000 to $150,000 per house—that a homeowner would have to wait decades before the investment could be recouped. "In a retrofit situation, it can cost a lot of money to save a small

CONSTRUCTION

Basement: Ceiling sprayed with open-cell spray polyurethane foam (adds thickness and R-value)

Walls: 2x4 construction filled with cellulose; 4 in. of foil-faced polyisocyanurate foam outside of sheathing for a total of R-39

Roof: 6 in. of polyisocyanurate insulation installed above the existing roof sheathing, topped with a layer of plywood; 8 in. of open-cell spray polyurethane foam (Icynene) installed between the existing rafters for a total of R-59

Windows: Double-pane (U-0.33) windows by Pella

MECHANICALS

Heating: Oil-fired steam boiler in each unit

Water: Main boiler in unit 1; on-demand gas water heater in unit 2

Ventilation: Heat-recovery ventilators (one for each apartment)

RESULTS

Energy reduction: 65% (heating fuel)

Annual savings: $2300 per year

Payback period: 61 years. If the cost of the roofing and siding are subtracted, payback is reduced to a little over 35 years.

Cost comparison

Not insulating your basement floor saves you from $1.80 to $2.50 per sq. ft. in materials.

WALL INSULATION

Deep-energy retrofit

A typical 2x4 wall insulated with fiberglass batts has a whole-wall R-value of about 10. Many deep-energy retrofits aim to insulate walls to R-40, which typically requires all of the siding to be removed and the addition of 4 in. to 5 in. of polyisocyanurate rigid insulation or spray polyurethane foam.

Practical takeaway

Unless your home's existing siding is in bad shape, it's hard to justify the cost of installing exterior wall foam. If your existing siding is sound, your best retrofit option is careful air-sealing work from the interior with canned spray foam. Typical leakage areas include the gap between the baseboard and the finished floor; electrical boxes; and cracks behind window and door casing.

Air-seal, then insulate. *If you can't afford to add insulation to your walls, address simple air-sealing measures such as filling the gaps around windows, electrical boxes, doors, and recessed lights in the ceilings.*

Performance comparison

Above-grade walls represent most of a typical house's thermal envelope, and an R-10 wall leaks heat at four times the rate of an R-40 wall. Although air-sealing an R-10 wall will surely increase its performance, it will not rival an R-40 wall.

Cost comparison

Installing thick exterior-wall foam and new siding on a typical house costs tens of thousands of dollars. Blower-door-directed air-sealing work might cost $700 to $1000 per house.

WINDOWS

Deep-energy retrofit

Single- or double-glazed windows are usually replaced with new triple-glazed windows with full-thickness (1⅜ in.) glazing. This glazing is better than thin ⅞-in. or 1-in. glazing.

Practical takeaway

The cost of installing high-quality replacement windows can be staggering; as a less expensive alternative, consider installing low-e storm windows over tuned-up windows in good working order and that have been weatherstripped.

Retrofit results

Cost: $148K
Annual savings: $2490

Alarmed by the implications of the global climate-change crisis, Cador Price-Jones embarked on a major retrofit of his Massachusetts duplex (also pictured on p. 56).

Location: Somerville, Mass.

Size: 2966 sq. ft. (duplex)

Renovation cost: $50 per sq. ft.; $148,300 total

CONSTRUCTION

Basement: 3 in. of closed-cell spray foam (R-18) applied between the studs of a 2x4 wall built against an 8-in. block foundation

Walls: Existing 2x4 walls filled with dense-pack cellulose; new 2x2 frame installed on exterior and filled with 4 in. of closed-cell spray foam for a total of R-37

Roof: Attic floor air-sealed and filled with 17 in. of loose-fill cellulose for an R-value of 60; 2 in. of spray foam air-seal the eaves

Windows: Main house windows are double-glazed, low-e, argon-filled units by Jeld-Wen; basement windows are double-glazed hopper units by Harvey Industries

MECHANICALS

Heating: Modulating condensing gas boiler, 22,700- to 75,200-Btu rated output, 95% AFUE

Water: 60-gal. Superstor indirect hot-water tank

Ventilation: Heat-recovery ventilators (one for each apartment)

Photovoltaic: 5.25kw package system by Nexamp

RESULTS

Energy reduction: From $5650 per year to $3160 per year

Annual savings: $2490

Payback period: 60 years

amount of energy," says energy consultant Michael Blasnik. "Going from R-19 to R-40 walls or R-30 to R-60 ceilings doesn't save a whole lot of Btu—and the cost of that work is potentially tremendous."

There's no easy way to calculate the payback period for many deep-energy retrofits, in part because a major overhaul of a building's shell inevitably includes many measures (for example, adding new siding or roofing) that aren't energy-related. Although these elements don't make a significant contribution to a home's energy performance, they may greatly enhance the home's aesthetics and value.

Those of us without a Midas budget will need to settle on a less ambitious approach to energy savings than a full-blown deep-energy retrofit, and that's OK. Less expensive and less invasive retrofit measures, typically referred to in the industry as weatherization, have payback periods of 15 years or less. □

Martin Holladay is a contributing editor.

Performance comparison

Good triple-glazed windows have a U-factor of 0.17 to 0.20. A low-e storm window won't achieve the same performance. Installed over a single-pane wood window, a low-e storm window provides a total U-factor of 0.40, while a low-e storm window installed over a double-pane wood window provides a total U-factor of 0.34. (The lower the U-factor, the better.)

Cost comparison

The cost to install a low-e storm window ranges from $120 to $160. The installed cost of a new triple-glazed window is about $800 to $1200.

HVAC

Deep-energy retrofit

Most deep-energy retrofits include air-sealing measures. Once infiltration rates have been reduced, an older house requires a good mechanical ventilation system. Options range from low-sone bathroom exhaust fans controlled by timers to heat-recovery ventilation systems with dedicated ductwork.

A new heating unit is also a quintessential upgrade in many deep-energy retrofits. New furnaces or boilers are most often efficient sealed-combustion models. The fuel type is relatively unimportant, because the fuel demands of the newly renovated home will be low.

Tight ducts save money. *Sealing leaky ductwork can be done in several ways, but mastic and fiberglass-mesh tape are among the best options.*

Practical takeaway

If you've done any air-sealing work, a mechanical ventilation system is essential. Exhaust-only systems are much less expensive than a system with a heat-recovery ventilator. If you can't afford an HVAC overhaul, you should at least have ducts tested for leakage and sealed.

Performance comparison

Replacing an 80% AFUE (annual fuel utilization efficiency) furnace with a 92% AFUE furnace will cut energy use 13%. Sealing ducts may save an additional 5% to 20% of your energy use.

Cost comparison

The installed cost of a new 92% AFUE furnace ranges from $3000 to $6000. Duct sealing and repair costs between $250 and $500 per house.

Photos: left, courtesy of Green Building Advisor; right, courtesy of Advanced Energy.