Tightening Up a Two-Family Home

Chasing down and fixing energy leaks in an old house can be tricky and expensive, but utility incentives may help

by Brian Butler

I'm a Boston-area contractor who specializes in energy-efficient construction and remodeling. My company recently completed an energy retrofit and remodel of my own house in Medford, Mass., undertaken as part of a pilot program administered by the regional electric and gas company National Grid. To demonstrate the feasibility of reducing energy use in existing structures by 50 percent or more, the utility provided partial funding for this and several other deep-energy retrofit projects in Rhode Island and Massachusetts.

The house is a two-family Dutch colonial built in 1908. It has two apartments totaling about 3,200 square feet. Though previous owners had replaced the siding, its thermal performance was dismal. The wall cavities were uninsulated, as were most of the third-floor ceiling cavities. The gambrel rafters had some loose batts, and there was spotty cellulose in the attic ceiling. Space heating was provided by an overworked pair of natural-gas boilers and distributed by steam radiators, with domestic hot water from 50-percent-efficient standing-pilot tank-type heaters. Blower-door tests showed that both units leaked at around 3,500 cfm.

My plan for the renovation was to insulate the existing framing cavities, wrap the entire structure in rigid foam, replace the windows, and upgrade the mechanical systems. By moving into the upper unit while the work was going on, I could build out the interior walls in the lower unit, add more insulation inside and out, and try to achieve the highest level of air-sealing possible in an old house like this. The upstairs unit wouldn't get the interior insulation or air-sealed drywall — which would result in slightly lower insulation values — but it would still make solid gains in overall efficiency.

To keep the look of the original house, I opted for an "outie" window configuration that would leave the plane of the glazing more or less in line with the siding.

Exterior Insulation

The first step was to have a cellulose contractor dense-pack the uninsulated 2x4 wall cavities from the exterior (**see Figure 1**). Then, after stripping off several layers of existing siding, we covered the 7⁄8-inch board sheathing with a carefully lapped and taped layer of HardieWrap weather barrier. To head off air infiltration between the framing members in the window openings, we also lined the rough openings with strips of HardieWrap, which we sealed to the housewrap outside and to the interior plaster on the inside.

Figure 1. Because the original balloon-framed walls had never been insulated, dense-pack cellulose was easily blown into the empty stud cavities from the exterior.

Next came two layers of 2-inch foil-faced polyiso board and a single layer of 1-inch, with the seams between layers staggered and sealed with Dow Weathermate tape. We used as few screws as possible for the first two layers, but screwed the top layer to the sheathing with a roofing cap at each corner. Finally, to provide a ventilated nailing base for the fiber-cement siding and to better secure the foam, we fastened vertical 1x3 strapping through all three layers and into the studs with 8-inch-long roofing screws (**Figure 2, page 56**).

The outer layer of foil facing serves as the drainage plane and a primary air barrier; the housewrap, now buried under 5 inches of rigid foam, acts as a secondary air barrier.

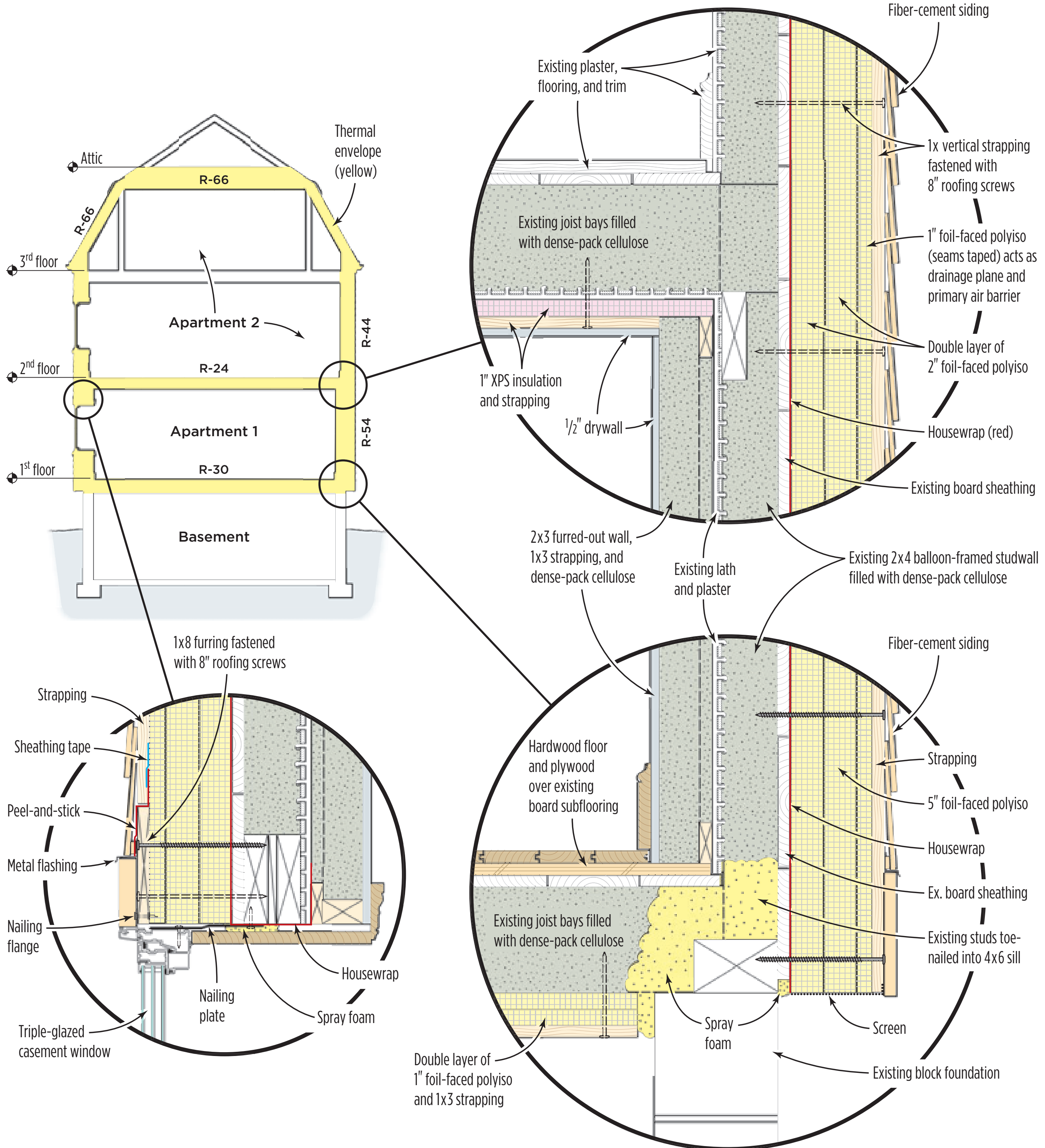
Windows

Because of the building's orientation and shade from neighboring houses, we were limited in the amount of passive heat gain we could collect through the windows. To make the most of what was available, we used Thermotech casements on the south side of the building; these units have a solar heat-gain coefficient of 0.61 and a low U-factor of 0.19 (thermotechfiberglass.com). Most of the other windows came from EcoShield, a small manufacturer in Upstate New York (ecoshieldwindows.com). We also installed one tilt-turn window from German manufacturer Schuco (schueco.com/web/us) in a location where an outswing window would have interfered with the entry stair.

One way to install "outie" windows is to extend window bucks from the rough openings to the depth of the foam. But this creates a thermal bridge, plus it takes up space within the rough opening. While the space issue is easy to deal with in new construction, we didn't want to reframe the openings or downsize the windows. So instead, we used a method similar to one common in Europe: We fastened the window frames with Simpson nailing plates, cantilevering them so the nailing flanges would be flush with the strapping on the exterior foam (**see illustration, facing page**). For added strength we used 1-by furring around the window openings, fastening these boards with long screws through the foam into the framing. We then attached the window flanges to the furring. This method may sound a little shaky if you're used to fastening windows directly to solid lumber, but once the exterior trim was fastened to the 1-bys and the windows themselves, the assembly was extremely solid. Those windows aren't going anywhere.

In the upstairs unit — because we wouldn't be

Adding Thermal Layers to an Old House



Both the owner's downstairs apartment and the rental unit upstairs received new high-efficiency windows, dense-pack cellulose in the uninsulated framing cavities, and a thick exterior layer of rigid foam. Airtight drywall and an additional layer of cellulose in the lower unit increased the R-value of the wall system only modestly — but reduced air infiltration to a fraction of that in the unit above.

Figure 2. Energy-efficient casement windows were cantilevered beyond the original rough openings, secured with metal ties, then surrounded with snug-fitting rigid foam, which also serves as the wall's drainage plane.

removing the interior trim — we fastened the metal straps to the original window jambs, which were reinforced with blocking in the sash weight cavities.

Sealing and Insulating the Attic

Air-sealing the eaves of an existing structure can be a challenge. One well-known solution — the "chain-saw retrofit" — wasn't practical with our gambrel roof, because cutting off the rafter tails would have seriously weakened the roof structure. Instead, we did the best we could by cutting and fitting the housewrap around the rafter tails, then sealing the edges with canned spray foam. The steep gambrel rafter bays later received 10 inches of closed-cell foam, completely burying the 2x4 rafters and forming a continuous seal with the edges of the housewrap. (The foam also stiffens the whole roof assembly nicely.)

Figure 3. The roof framing in the attic mechanical room is encapsulated in a thick layer of closed-cell spray foam, bringing all the hvac equipment and ductwork within the building's thermal envelope. Plywood panels, fastened to blocking before the foam was applied, provided solid mounting surfaces where needed. To meet the fire code, the exposed foam was coated with intumescent paint.

Most of the attic floor — which lay beneath the less-steeply-sloped upper part of the gambrel roof — got a flash coat of foam for air-sealing, followed by a 20-inch layer of loose-fill cellulose. About a fourth of the attic was partitioned off for use as a small mechanical room, its walls and rafters insulated with spray foam, bringing the space inside the thermal envelope (**Figure 3**). Access to the mechanicals is through a scuttle with a drop-down ladder. We removed the now-unneeded brick chimney, which left a convenient chase for running water lines, HRV ducts, and electrical conduit to the utility room in the basement.

Floor Insulation

Given that the basement ceiling was too low to allow for living space, I decided to place the thermal envelope at the first-floor joists (except for a small centrally located utility closet). Insulating the basement ceiling was simplified by the fact that we were planning to replace all the existing wiring and plumbing anyway.

Figure 4. Working in the cellar, the crew applied foil-faced rigid foam to the bottoms of the first-floor joists, then sealed around the perimeter with spray foam; the joist cavities were later dense-packed (left). To further reduce air movement between the basement and living space, the author laid housewrap across the subfloor above, taping the seams and sealing it to the drywall perimeter before laying the finish flooring (below).

Because the house is balloon-framed, with its studs toenailed to a 4x6 sill, the first order of business was to spray closed-cell foam from a five-gallon kit against the exterior sheathing around the sill, filling the space where the studs and joist ends meet (but taking care not to let the foam expand beyond the bottoms of the joists themselves). Next, we fastened a layer of 1-inch foil-faced polyiso to the bottoms of the joists (**Figure 4**). We held the edges of the sheets an inch or so back from the sill, then filled the gap with more foam, which expanded enough to become continuous with the foam applied earlier. Later, after the enclosed bays were filled with dense-pack cellulose, we applied a second layer of rigid foam followed by strapping.

Interior Furring and Insulation

Although the shell was now well-insulated, we furred out the exterior walls of the downstairs unit to provide space for wiring and mechanicals and another 4 inches of cellulose (**Figure 5, page 60**). We first mudded over any cracks and abandoned receptacles in the original plaster, then nailed up three courses of horizontal strapping to each wall — one at the bottom, one at mid-height, and one just below the intersection with the ceiling. We then toenailed 2x3 studs to the strapping.

The stud cavity gave us room to install Lessco receptacle boxes. Like conventional airtight rough-in boxes, these include a wide flange that seals to the drywall with spray foam or caulk, but they're easier to work with because there's more room to get at the wires. After the insulation sub had netted and blown the cavities, we installed the drywall, sealing it to the electrical boxes with caulk.

To provide good thermal separation between the home's two units, we also insulated the cavities of the walls around the two stairwells. And we added an inch of extruded polystyrene to the bottoms of the second-floor joists, then had the floor cavity dense-packed. This separation between the units will provide a useful "test lab" to the utility as it tracks energy usage, since the bottom unit is sealed and insulated to a higher level.

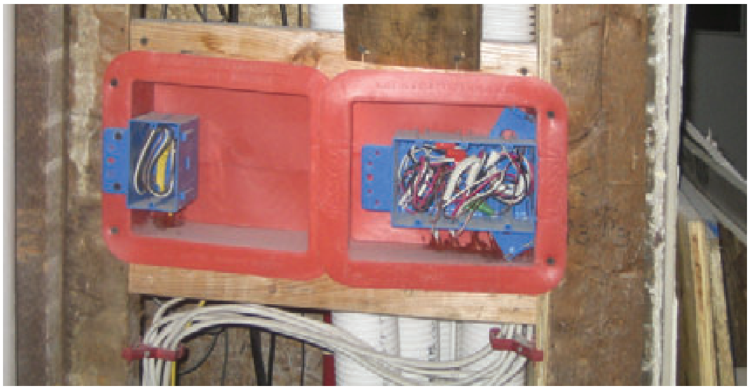


Figure 5. An air-sealed layer of XPS in the downstairs ceiling minimizes heat loss to the upstairs unit (above left). The exterior walls of the first-floor apartment were also furred out with 2x3s to provide room for additional cellulose, as well as space for the HRV ductwork (above). To tighten the wall assembly even more, the author used an airtight drywall approach, installing receptacle boxes inside airtight Lessco boxes (left).

Mechanicals

A three-head ductless minisplit from Mitsubishi provides heat for the downstairs unit; the upper apartment is heated with an AO Smith water heater piped to a Unico fan-coil system. Each unit is also equipped with its own 90-percent-efficient Zehnder HRV. A grid-connected 7-kw photovoltaic array supplies the lower unit with electricity.

Summing Up

Post-project blower-door tests show that air infiltration in the upper unit has decreased from an initial 3,500 cfm at 50 pascals to about 1,800. As expected, the lower unit is much tighter, at just 350 cfm.

Still, that figure was higher than our original downstairs goal of 187 cfm (a target that would have allowed us to hit a Passive House standard for old buildings). On investigation, we found that a good deal of that leakage was coming in around the electrical boxes, which apparently weren't caulked well enough when the drywall was hung. In hindsight I wish I'd supervised a little more closely, because it can be tough to get subs to fully grasp the importance of air-sealing.

We have our own blower door, so we've been able to track down most of the leaks with a smoke pencil and seal them with caulk or canned foam. In the case of the outlets, this involves removing the cover plates and injecting canned foam around the perimeter of the boxes through a straw inserted in the gap between the wallboard and the rough-in box, taking care to keep the foam out of the electrical boxes themselves. The master bedroom hasn't yet been tiled and finished, so there's still some low-hanging fruit available that should help us close the remaining gap.

The total project cost — before incentives — was $275,000. About $60,000 of this was directly attributable to energy improvements over and above code requirements. The utility pilot incentive totaled $54,000.

***Brian Butler** owns Boston Green Building in Allston, Mass.*