field notes

A Farmhouse Renovation

Short of a complete teardown, there's plenty this homeowner did to improve the energy efficiency of his old house.

MIKE ROGERS

by Mike Rogers

When my wife got accepted to medical school at the University of Vermont, our family moved to Burlington and started looking for a house. In August 1997, we bought a humble two-story farmhouse a few blocks from the hospital. It wasn't love at first sight; it was more that the home met our top four criteria—location, location, location, and affordability—and it seemed structurally sound, even if it did need work. I figured that I could work on the other issues, such as comfort, energy efficiency, and aesthetics.

Our farmhouse was built in the early 1920s. It had a 660 ft² footprint, built on a stone foundation with an unconditioned basement and a walk-up attic. The attic floor had 6 inches of R-16 rock wool insulation. The walls were back-plastered—meaning that a coat of lath and plaster was applied to the inside of the exterior sheathing with plasterboard on the interior surface, providing marginal air sealing—but were otherwise uninsulated. The existing single-pane windows either were loose and rattled or were too tight to move. The aluminum storm windows didn't move much better, and there was evidence of significant condensation in the form of mold growth on the sills with touches on the frame, especially on the second floor.

The well-worn old house had no mechanical ventilation, even in the two bathrooms. And though this was not as budget-busting as some of the other problems, there were signs, mostly in the form of traps laid throughout the house, of an ant problem. The house was heated with an oil-burning furnace. Although I don't know the occupancy habits of the previous owners, their annual oil bill was about $1,200—about 1,400 gallons—for space heating only.

The Challenges

My original goal was to significantly improve the energy efficiency, indoor air quality, and comfort of the home. If I had been able to fulfill my dream of building a new home, I would have made sure that it exceeded Energy Star requirements. Although I wasn't sure I could cost-effectively reach that level of performance in this home, it was a target very much in my mind.

In terms of increasing the size, I wanted to add an indoor space large enough for our two young children to play in when the temperature dropped below 0°F, a mud room so we could keep the outdoors out; and a laundry room so that we wouldn't have to do laundry in the cramped, short basement. I also needed to incorporate a home office into any changes.

I needed to do all this without obliterating our budget. Fortunately, my labor was free, and my brother, Chris—who happens to be a custom builder in Berkeley, California—came East to provide yeoman's assistance in the early stages of the project. As time went on, I would find myself very grateful for his help and ongoing advice. As Chris was to tease me again and again, "The thing

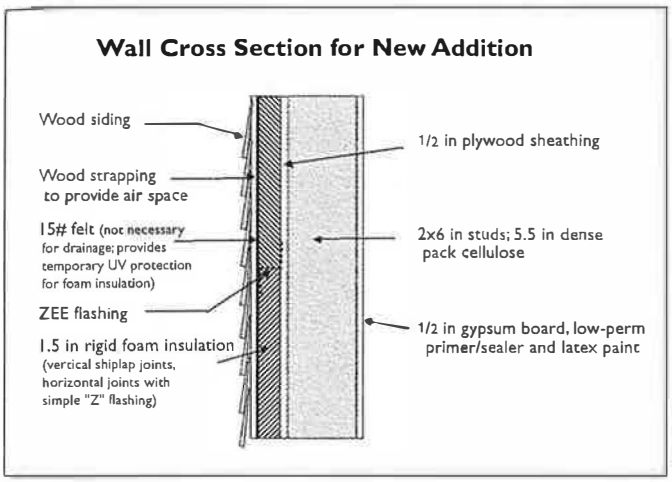

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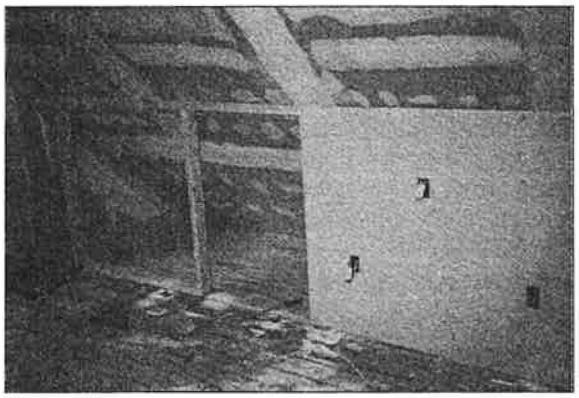
Figure 1. Drawing cross section of wall construction in new addition.

I love about this work is that it's fast, clean, and cheap!"

The Changes

To begin with, I built a 350 ft² slab-on-grade shed roof addition off the back of the house. This is very much in line with the local architecture—which is a mixture of funky farmhouses and late-Victorian cottages—and fits well with the house. Because the winters can be frigid, the construction in the addition exceeds the Vermont Energy Code requirements. The walls are 2 x 6 construction with two-stud corners: The cavities are insulated with dense-pack cellulose (chosen in part because I wanted to insulate wall cavities in the existing structure, as I explain below), with 1½ inches of rigid foam insulation. I placed the insulation on the exterior, to decrease the effect of thermal bridging across the studs and to raise the temperature of the sheathing to reduce the chance of condensation in the cavity (see Figure 1). I put in new high-performance windows (double-pane, low-e argon, and, for a few fixed and casement windows on the north side, triple-pane, low-e argon). The exterior of the foundation frost walls is insulated to the footings, and there are 2 inches of EPS foam under the entire slab. As a further thermal break, I used 1½-inch-thick, 4-inch-deep leftover foil-faced polyisocyanurate insulation, butting into the subslab insulation, around the interior perimeter of the slab.

The addition's cathedral ceiling uses 2 x 12 rafters (necessary because of the snow load on the 3/12 sloped roof) dense-packed with cellulose. I put 1½ inches of rigid foam on the underside of the rafters. This is not how I would do it now; I would prefer to have the foam on top of the sheathing (See "Unventing Attics in Cold Climates," *HE* Nov/Dec '99, p. 27). However, the original drawings included a provision for venting the ceiling in accordance with the building code. The code official would not initially approve an unvented ceiling, and work was begun with this requirement in mind. I was eventually able to convince the code official to allow the unvented construction, but by that time the framing was already completed. Because of the sec-



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By moving the thermal envelope and air/vapor barriers to the rafters, insulating and air sealing was simplified.

Things I Would Do Differently

Of course, in hindsight, I've made a few mistakes along the way. And in the two years since I started this project, materials, equipment, and techniques have continued to evolve. If I undertook this remodel today, there are several things that I would do differently.

I'm generally pleased with the exhaust-only ventilation strategy. During the heating season, the furnace comes on periodically to mix the air. However, in retrospect, I should have installed a multiport exhaust fan to service the second-floor bath and the three bedrooms. I believe this would have increased exchange rates in the bedrooms. Given the tightness I expect to achieve in the house, I might also have considered a heat recovery ventilator.

In a rush, I only ran one wire to the first-floor bath fan, a Panasonic fan/light combo unit in the shower. While this has its advantages, especially in signaling that the ultraquiet fan is on, it does limit my ability to integrate the fan into my ventilation strategy without wasting power to the light.

Although I got the quietest range hood I could find at the time, it's still not as quiet as I would like. Having had a couple of walls opened, I should have installed a remote fan, which would be whisper quiet at the grill and still be able to move 100–200 CFM while we're cooking.

On the exterior insulation, I began by taping the joints. This was a bit tedious, and I'm not convinced the tape will stick forever (although the building felt provides a redundant drainage plane anyway). I would have much preferred using tongue-and-groove or shiplap foam boards, and using a Z flashing for the horizontal joints, a tip I picked up from Joe Lstiburek at a Vermont Energy Star Homes conference.

Despite the perimeter insulation in the addition, I should have used 4 inches of rigid insulation below the slab, rather than the 2 inches I did use.

I would not assume that "professional and workmanlike manner" for HVAC contractors meant the use of mastic. Next time, this will be in the contract.

I did not like the jamb liner on the Pella double-hung windows I installed. The jambs on both the Marvin Ultimate and the Integrity windows looked better, and the sashes are easier to operate.

ond floor windows, I did not have room to add foam on top of the original sheathing and raise the roof deck. Thus, I decided to continue with the original design, but dense-packing instead of venting. While this does raise concerns about moisture on the underside of the roof sheathing, I believe that with the dense-pack cellulose and the foil-faced air/vapor barrier, moisture will be much less of a problem than it is in a conventionally vented cathedral ceiling.

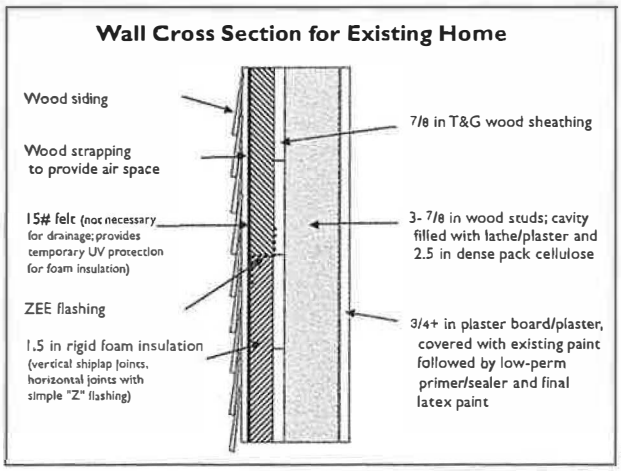

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Figure 2. Drawing cross section of wall construction in existing walls.

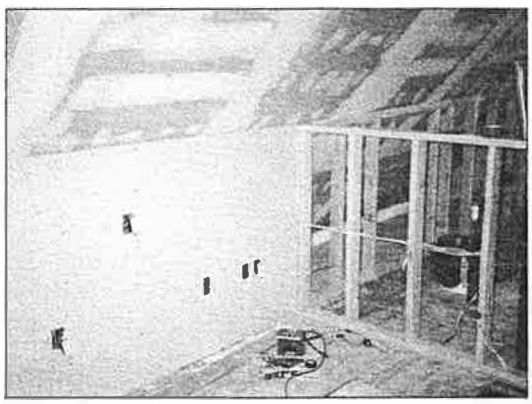
The Renovations

Unfortunately, the rest of the house wasn't as straightforward. Because 1 to 1½ inches of back plaster was applied to the inside of the sheathing before the walls were closed in, I could fit just under 2½ inches of insulation in the wall cavity. (The insulation was shoehorned into the void between the back plaster and the plasterboard in the existing walls.) With dense-pack cellulose at about R-3.5 per inch, this gave me insulated cavities of only R-8. And with 2-inch-thick unplaned studs on 16-inch centers, my whole wall rating would be significantly lower (see Figure 2).

While I did open up some of the walls, which allowed me to remove the back plaster, I did not have the time or the budget to gut the entire house. I also wanted to avoid contact with the asbestos siding, which had become brittle and had started to deteriorate. Because the asbestos shingles were applied over the original clapboards and cedar shingles, my changes meant removing the asbestos. The solution I went with was to remove the siding on the north and west sides, adding 1½ inches of rigid foam to the exterior of the sheathing. I disposed of the asbestos as hazardous waste. I found the simplest and cheapest way to do this was to pay $60 to have the dumpster lined and to pay an additional $20 per ton for disposal. The total cost was around $400, but this amount also includes charges for nonhazardous waste.

Because the wiring throughout the house was vintage knob and tube, I opted to replace it before the wall cavities were insulated. I believe the dense-pack cellulose contributes to the airtightness of the house, adds significantly to the R-value of the assembly, and decreases the air transport of moisture into the wall. And although it is not rated as a pesticide, I've heard anecdotal stories of the borates in cellulose insulation effectively ending pest problems. We haven't seen evidence of ants since the walls were insulated.

New windows are expensive, so replacing windows isn't always cost-effective purely from an energy standpoint. However, I had already decided to replace the windows for a variety of other reasons, including convenience, comfort, noise reduction, ease of maintenance, and concerns about lead paint on the existing windows (the friction from sliding windows can release lead dust into the home). Since I was removing the siding, and because I knew there was no air sealing around the original window frames, I decided that it would be just about as easy, and certainly more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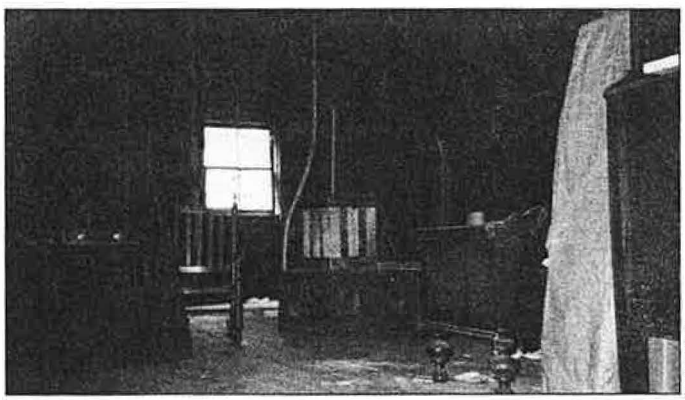
The kneewalls will contain built in bookcases, and the conditioned area behind will be used for storage.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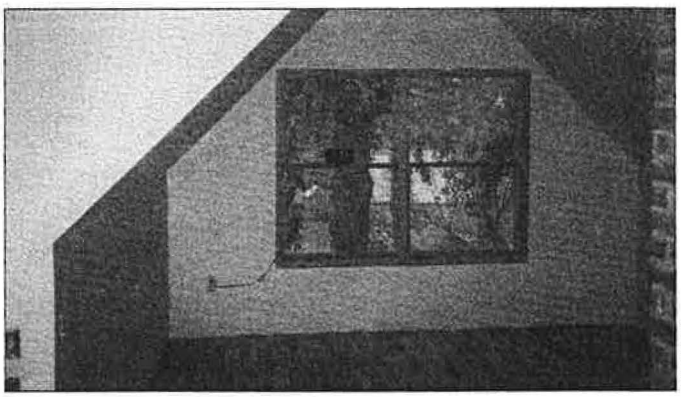
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The picture on the left was taken at noon on a sunny day in June before work began. The picture on the right was taken the same time of year after new windows were added. By adding several new windows and opening up two walls, the need for lights during the day has been greatly reduced.

effective, to completely remove the existing windows, frame and all. This not only allowed me to install the energy-efficient glazing, but also made it possible to air seal around the frame, as is done in new construction.

The approach to the walls and windows decided, I chose to bring the entire attic into the thermal envelope of the building. Adding insulation on top of the floor, even if it had been effective, would have decreased some very usable storage area. I dense-packed the rafter bays and, as in the new addition, applied rigid foam to the bottom of the rafters, from floor to ceiling. My approach allowed for a cleaner envelope without the numerous electrical penetrations and funky framing gaps that existed in the attic floor. Accessing these holes and gaps would have required pulling up more floorboards. Although I later built knee-walls, I not only avoided the more difficult problem of insulating and air sealing a side attic, but also preserved conditioned storage space and allowed for built-in bookcases. *No-Regrets Remodeling* contains a very good discussion of the advantages and disadvantages of this approach. Again, I would have preferred to place the rigid insulation on top of the existing roof sheathing, but with a relatively new roof, this would not have been cost-effective.

Other Changes

In addition to the envelope, I made several other changes to reduce total energy use in the home.

The house originally, and curiously, had minimal glazing on the south side. I increased the number of windows from two to six in the existing structure. This allows for some increased solar gain. Because I also opened up the interior, removing a couple of walls on the main floor and a south closet on the second floor, this also eliminates the need for lights in most rooms during daylight hours.

I replaced many older fixtures of questionable safety with fluorescent and compact fluorescent fixtures.

As I purchased or replaced appliances, such as the refrigerator and dishwasher, I selected energy-efficient models.

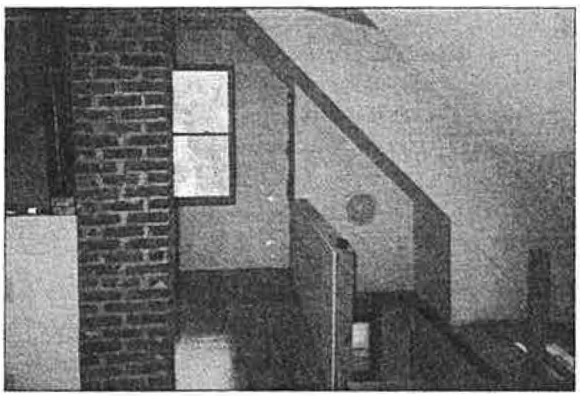
Space and Water-Heating Equipment

Currently, the house is heated by the furnace that was here when we moved in, the oil burner having been replaced by a gas conversion burner. The com-

Table 2. Summary of Improvements

	Original House	Improved Original House	Addition
Foundation	Stone	Stone	Slab-on-grade with perimeter subslab insulation
Basement	Uninsulated, unconditioned, within thermal envelope	Uninsulated, unconditioned, outside thermal envelope (insulation added between basement and first floor)	
Walls	2 x 4, no insulation, back-plastered	2 x 4, back- plastered, dense-pack cellulose @ R-8, 11/2 -in exterior foam @ R-7.5 to R-11	2 x 6, dense-pack cellulose @ R-19; exterior foam @ R-11
Ceiling	6-in rock wool, many voids, and air bypasses	Cathedral, 6-in rafter bays dense-packed @ R-21.5, 11/2 -in interior foam @ R-11; 2-ft top attic dense-packed solid	Cathedral, 11 1/2 rafter bays dense-packed @ R-41; 1 1/2 -in interior foam @ R-11
Windows	Wood single-pane windows with aluminum storms/screens	Aluminum-clad wood double-pane, low-e, argon-filled. Some with low conducting spacers. Selected windows on north side, aluminum-clad wood triple-pane, low-e, argon-filled	
Tightness	Not measured; visible bypasses in attic; loose-fitting windows and gaps around doors; electric, phone, and cable penetrations ineffectively sealed	Not yet measured; target .35 ACH; attic thermal/air boundary chosen to minimize leakage; new windows/doors with air sealing around frames; dense-packed walls to reduce air movement; penetrations sealed; weak spot where second-floor porch meets wall	
Space heating equipment	65% AFUE-burning furnace	65% AFUE gas furnace, scheduled for replacement with 90% AFUE sealed-combustion furnace	Hydronic radiant floor, run off hot water heater
Water heating	Atmospheric gas efficiency information is not available	61% AFUE gas sealed-combustion	
Lighting	One hard-wired fluorescent in kitchen; CFL in bathroom	Predominantly hard-wired fluorescent/CFL fixtures, especially in high-use areas; liberal use of CFLs in other fixtures; exterior light activated by timer/motion sensor	
Ventilation	No mechanical ventilation	Panasonic fans in both bathrooms, one on Airetrac timer to provide general ventilation; range hood	
Appliances	25-year-old refrigerator	Energy Star-qualifying refrigerator and dishwasher	

bustion efficiency of the combination is only about 65%. This is scheduled to be replaced later this year by a 90% annualized fuel utilization efficiency (AFUE) sealed-combustion furnace with a variable-speed blower. The addition is heated by an in-floor radiant system run off the hot water heater through a heat exchanger. The addition is one step lower than the rest of the first floor. The step-down collects the cold air, which, being more dense, seeks the lowest point. I also installed a programmable thermostat. The radiant heat eliminates a cold floor and creates a separate zone, with the kitchen, for the most frequently used rooms of the house. The heat in the kitchen is supplied by a panel radiator, not an in-floor loop. My preference would have been a hydronic system for the entire house; however, the conversion would have been prohibitively expensive.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The same room as above right, after windows were added.

The water heater is a sealed-combustion unit. I chose sealed-combustion heating equipment not only for its efficiency, but also because I believe it is safer, especially given my ventilation strategy, which I describe below. In fact, I don't believe we should be installing natural-draft water heaters in the conditioned space of homes today due to the risk of backdrafting.

The attic is currently not heated but is used as an office. Although it is typically several degrees cooler than the rest of the house, the space is maintained at comfortable conditions by waste heat from an incandescent bulb, computer equipment, and body heat and transfer heat from the rest of the house (since it's within the thermal envelope). I intend to try this for another year before considering whether to install heating in the attic.

Indoor Air Quality

To provide ventilation in the house as it became tighter, I opted for an exhaust-only ventilation strategy. This involves the use of a Panasonic FV-08VQ90CFM fan, located in the main bathroom, which provides about 40 CFM of continuous background ventilation using an Airetrak controller. The controller is set to provide continuous low power to the fan. The fan can be boosted to full power—about 90 CFM—for 20 minutes by merely pressing a button.

Another Panasonic fan, model FVO7VQL70CFM, provides intermittent spot ventilation in a first-floor bathroom. We chose a gas range because we prefer cooking with gas, and because we live in an area prone to occasional power outages. However, we have a kitchen exhaust fan, and we use it religiously when we cook. We also use a gas dryer from time to time, especially in the winter when I'm too timid to venture outside to hang clothes on the line, not to mention the fact that it would be days before the laundry dried into stiff boards. This contributes slightly to the total house exhaust.

By removing large amounts of moisture at its source—the bathrooms, kitchen, and laundry—we've been able to maintain reasonable humidity levels in the house. Condensation has occurred only a few times on a couple of windows after a -25°F night. By controlling indoor humidity levels and by slightly depressurizing the house, I'm also limiting the amount of moisture that can migrate into the wall assemblies.


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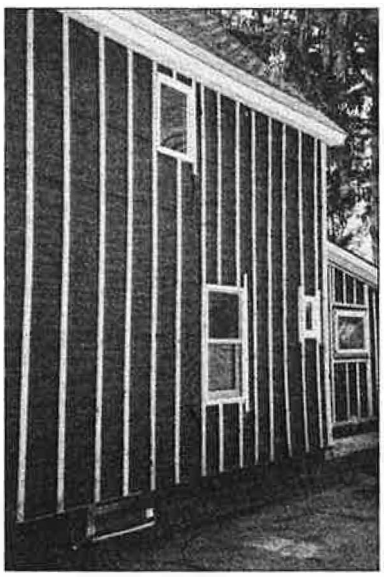
The attic room before remodeling changes were made.

Results

Even though the improvements are not complete, I've seen significant results. With the old furnace still in place, the cost for space heating has been about $500 for each of the past two winters—a more than 50% reduction, though I am comparing my gas bill to the previous owner's oil heating bill. And this reduction is with a 50% *increase* in conditioned area. With the new basement insulation and the new furnace, I estimate annual heating fuel costs will be in the $300 range. Electric usage, with a full-time office in the home, is about 200 kWh per month in the summer, and 400 kWh in the peak heating season. The reason for the 100% increase in kWh, despite the fact that we use gas for heating, cooking, and drying clothes, is that lighting costs increase significantly during the winter months—from 16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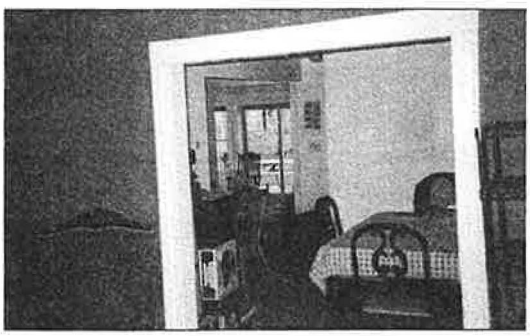
Strapped exterior, ready for siding

hours of daylight in the summer months to a mere eight during the winter months. I also believe that the old, single-stage furnace blower is a large contributor to our hefty energy increase.

The house is less drafty, much more comfortable, and quieter than when we moved in. Condensation on windows or cold walls is not an issue. And, with the exception of one night last summer, we were comfortable without air conditioning, or even a fan. Assuming reasonable success with my airtightness measures, I should qualify for an Energy Star rating once work is completed. If I get the rating—which means that my home received an 86 or higher HERS rating— I'll definitely highlight this if I sell: It will mean that potential buyers will have access to energy-efficient mortgages, which typically have a larger spread. And, I can't put a price on my personal satisfaction in achieving an increasingly well-known metric, since most older homes can't achieve an 86 rating cost-effectively.

Hurdles

The three biggest obstacles to renovating the house have been lighting, proper sizing and installation of the HVAC equipment, and financing.



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The house is much more comfortable now— less drafty and better lit.

Lighting

When I began this project two years ago, it was difficult to find aesthetically pleasing fluorescent light fixtures with electronic ballasts. Of course, I could have built my own fixtures for some applications, but like most builders, this was not how I wanted to spend my time. Fortunately, even in the past two years, the technology has improved and availability has increased. It's now possible to find a nice selection of fluorescent fixtures at reasonable prices. This makes it easier to use energy-efficient lighting in any project.

HVAC

When it came to the heating system, I opted to subcontract the work. Some of the changes required moving ductwork. The existing ductwork was beautiful shop-built sheet metal with joints sealed with mastic. Busy on other projects, I did not supervise the installation of the new duct system. The new work suffered greatly in comparison: droopy flex duct, and not even lipservice paid to sealing new joints. In fact, the contractor claimed that ductsealing was "not important in residential work." I should have specified in writing how I wanted the job done. As it was, I complained, had a lengthy discussion, renegotiated the price, and did the sealing myself, using a combination of mastic and foil tape.

Sizing of the HVAC system was another disappointing story. When it came time to get bids on replacing the furnace, all that most contractors wamted to know was the floor area of the house and what the existing equipment was. I quickly learned that if I did not do the *Manual J* load calculations myself with the appropriate software, and specifically request equipment in a certain range, I would get a furnace with twice the Btu output I needed. One of the exceptions was Vermont Energy Contracting and Supply. They looked at the load on the building and determined the appropriate equipment. I felt even better when we compared our calculations and came up with the same numbers. They were also one of the few contractors who didn't give me a blank stare when I talked about some of the options I was considering, such as the radiant floor in the addition.

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Physical and pressure barriers helped keep dust, odors, and fumes out of the living space.

Finance

On the financing side, I was unable to locate a bank that would give me a mortgage at purchase time for more than the purchase price, even for energy-efficient improvements. Since my improvements added significantly to the cost of the house, I've had to rely on creativity and scrounging for opportunities. I'm taking advantage of available rebates (see Table 1), and I'm relying on a variety of bridge loans. In conjunction with Energy

Table 1. Rebates and Savings

Program	Product Rebates	Savings
Vermont Gas Residential retrofit program	Wall insulation Paid $400	Loaned $800 at 0% interest
Vermont Gas Equipment replacement	High-efficiency furnace High-efficiency water heater	$400 rebate $100 rebate
Vermont Star Homes rebates on a variety of energy-efficient products and services	Fluorescent fixtures Ventilation system Home energy rating Refrigerator	$500 rebate $100 rebate $100 rebate, $350 if Home meets Energy Star level $50

Star, the Vermont Energy Investment Corporation has created a new energy efficiency loan. Unfortunately, this vehicle was a bit too late for me, and the interest rate was a bit too high. Once the work is completed, I will refinance.

Much of the fanfare surrounding energy efficient homes centers around the new-home market. Addressing energy use is certainly easier if it starts during the design process and continues through construction, commissioning, and ongoing use and maintenance of new homes. However, we can find enormous savings in existing homes, while making those homes healthier and more comfortable. This is surely good news in areas that are already built out with older homes, and for people who prefer to live in existing neighborhoods but who want the benefits of a high-performance home.

Mike Rogers is an amateur home builder who also works as a consultant on indoor air quality and residential energy efficiency for the Environmental Protection Agency's Energy Star program.