Optimized Strategy for Scaling Up Deep Energy Retrofit

West Hill House

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Table of Contents

Executive Summary

A Deep Energy Retrofit (DER) was successfully performed at a home on the west hill of Ithaca, New York, during the autumn of 2012. The West Hill House is a 1400 sf. ranch built in 1955 with a partially finished basement. The scope of work for this DER included:

- Attic: Removed existing fiberglass insulation. Thoroughly air sealed all penetrations of attic plane. Installed vent chutes and soffit blocking. Insulated to R-60 with cellulose insulation.
- Walls: Removed existing vinyl and wood siding. Removed degraded fiberglass where present. Dense packed walls with cellulose insulation. Installed window bucks, flashing and trim. Installed 2.5” Thermax. Reinstalled existing vinyl siding.
- Basement walls: Installed 2.5” Thermax on exposed basement walls. Removed sheetrock on approximately 130 s.f. of finished basement wall and insulated with 3” closed cell foam. The basement band joist was insulated with 2” closed cell foam.
- Windows and doors: Main floor windows were new double pane low-e vinyl windows and were kept and flashed/sealed. One basement window and three doors were replaced.
- Mechanicals: A new, sealed combustion boiler was installed. Pipe insulation was installed. Energy Star compliant ventilation (Panasonic Whispercomfort ERV and Whisperlite bath fan) was installed.

The results of the DER at the West Hill House are remarkable, and they met the objectives of the DER program.

Program Objectives	**Goal**	**Actual**
Total envelope air leakage	< 0.25 CFM50/ssf	0.14 CFM50/ssf
Above grade wall insulation	> R-25	R-29 on most walls
Labor and material costs	< $10/ssf	$9.55

Other Key Metrics	**Pre-DER**	**Post-DER**
Blower Door reading	2015 CFM50	722 CFM50
Radon testing	< 0.9 pCi/L	< 0.6 pCi/L

Executive Summary in Photos








Areas of Air Leakage Reduction

The West Hill house contained five areas of air leakage requiring significant attention during the deep energy retrofit.

1. Attic plane

The attic plane was a major source of air leakage. A thorough clean-out of the attic involved the removal of fiberglass batts by hand, followed by vacuuming of debris with a gas-powered insulation removal vacuum.

Attic insulation removal in progress.

Using the insulation vac to remove the last of the attic debris.

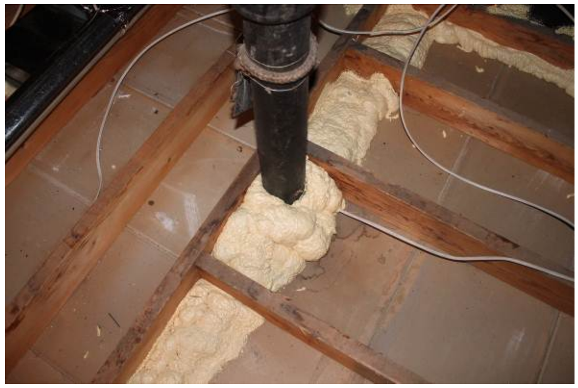
This restored the attic to a very clean condition, and it allowed complete inspection and sealing of air leaks in accordance with best practices for new construction. The follow leaks were sealed:

a) Top plates. Interior and exterior top plates were sealed with a coat of 2-part polyurethane foam. This sealed sheetrock/top plate junctions and wiring penetrations. On the exterior bearing walls, the top plates were sealed to the exterior foam sheathing, which extended between the rafter tails up to the vent chutes to form a wind block.

Spray foam used to seal top plates and electrical penetrations.

b) Electrical boxes for lights and smoke alarms.
c) Plumbing stacks.


Plumbing vent with air leaks.


The plumbing vent is now sealed.

d) Range hood vent, which passed through a roughly cut hole in the sheetrock.
e) Bath fan and ERV housings.
f) A very large chase around the CMU chimney, which housed both the fireplace flue and the old boiler flue. This chase, while originally covered with faced fiberglass, connected directly to grilles in the first floor wall on either side of the fireplace. Additional framing was installed to support a Thermax air barrier at ceiling level, which was sealed with two-part foam. Sheet metal and high-temperature caulk were used within 2" of the chimney itself.


A giant air leak around the chimney.


Chimney air sealed; metal dam provides 2" clearance between cellulose and chimney.

2. Main floor walls

With the exception of the garage wall, which contained some perlite and fiberglass, and the wall behind the kitchen sink, which contained a few pieces of fiberglass, the main floor wall cavities were empty.

The 2 x 4 wall cavities on exterior walls were completely empty.

A large bypass was discovered behind a bath tub on an exterior wall. After blocking the bypass with fiberglass to prevent blow-by into the interior of the house, the cavity was packed with high-density cellulose insulation.

Dense-packing the wall cavities.

Smaller leaks were associated with gaps in the sheathing, electrical penetrations, etc. Visible holes in the sheathing, such as those from stray hammer strikes, were sealed with one-part foam. Wall cavities were packed with high-density cellulose insulation. Complete coverage was verified with an infrared scanner. Additional air sealing was provided by the Thermax sheathing, which was sealed at top and bottom by a bead of one-part foam; seams were taped with Weathermate construction tape.

3. Windows and doors

a) First floor windows and one window in the basement media room were newer double pane vinyl windows. These were determined to be in good condition, with almost no detectable leakage around the fixed or moving parts of the window assembly. Tests with an electronic window coating detector indicated that the main floor windows had low-e coatings. Sealing the window exteriors with Dow straight flashing provided a small air sealing benefit.

b) The original wood doors were leaky, and they were replaced by new, tightly sealing fiberglass and steel doors. Adjustable thresholds were raised to seal visible gaps at the bottoms of the doors. Door frames were sealed with one-part foam.

c) One single-pane, steel-framed basement window was replaced with a new, double-pane low-e vinyl slider. Other basement windows had been caulked shut and covered over with XPS by the previous homeowner.

4. Basement sill plate and band joist

The basement band joist/sill plate assembly consisted of 2 x 8s on a CMU foundation. Small leaks were detected around the entire perimeter at points of wood/wood contact. Larger leaks were found at places where power, telecommunications, and radon utilities passed through the band joist. The band joist was sealed and insulated with 2” closed cell foam. The sill plate was left exposed to allow drying to the inside; however, the wood/CMU joint was sealed with one-part foam.

Spray foam in basement rim joist. In this photo, Thermax has not yet been installed on the walls, and the sill plate has not yet been sealed to the block foundation.

Basement wall exposed and ready for spray foam.

Spray foam on basement wall. It will need to be trimmed prior to sheetrocking.

5. HVAC equipment

a) Old boiler flue. The original boiler was an atmospheric boiler with 6" flue. Although it had a motorized vent damper, leakage was still detected through the draft hood. After a sidewall-vented, sealed combustion boiler was installed, the flue was capped at the chimney top, the thimble plugged and caulked, and the cast-iron cleanout caulked shut.

The existing heating system, a cast-iron, atmospherically vented boiler.

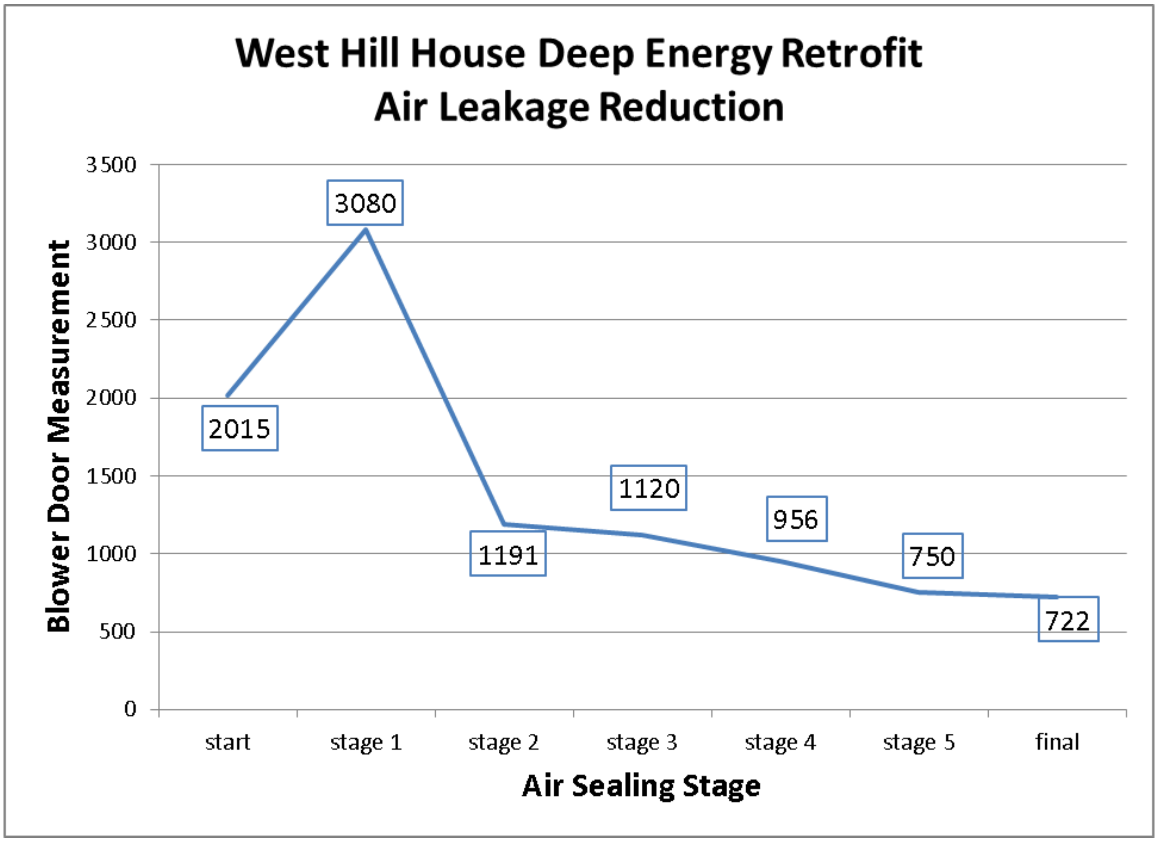
The new 95% efficient boiler.

b) Fireplace. The chase surrounding the wood fireplace was a large source of air leakage (see attic plane, above). In addition, the flue itself was found to be a major source of leakage, despite the presence of glass fireplace doors. A Lock-Top damper was installed over the open terra cotta flue, resulting in a 150-200 CFM50 reduction.

c) Range hood. After the penetration of the range hood ductwork through the ceiling plane was sealed, leakage was still detected through the range hood itself. A spring-loaded metal damper was installed in the ductwork below the depth of the attic insulation.

Blower Door Measurements

Blower door measurements were taken at several stages during the air leakage reduction process. The graph below shows the measurement at each stage, followed by a table listing the work completed during the stage.



Air Sealing Stage	CFM50	Work completed
Start	2015	
Stage 1	3080	• vinyl siding & old foam sheathing removed • walls dense packed • attic fiberglass removed
Stage 2	1191	• attic airsealed • band joists spray foamed
Stage 3	1120	• wall foam installed
Stage 4	956	• sealed fan ducts and exterior top plates
Stage 5	750	• Lock top damper, window flashing
Final	722	• Final round of blower door guided air sealing, mostly basement sill and band joist

Insulation Values

Insulation was increased in the attic, basement, walls, windows, and doors during the deep energy retrofit according to the schedule below.

Surface	Pre-DER	Post-DER
Attic	Nominal R-19 faced fiberglass: effective R-11 to R-15	Cellulose: R-60
Basement walls: Unfinished	Uninsulated block: R-2	2.5" Thermax + block: R-18
Basement walls: Finished	Uninsulated block, 2 x 4 wall, sheetrock: R-4	3" closed cell foam + block: R-20
Basement band joist	Uninsulated band joist: R-3	2" closed cell foam + 2.5" Thermax: R-31
Above-grade walls: Most walls	Uninsulated 2 x 4 cavity, wood siding, 1/2" polyiso, vinyl siding: R-8	Cellulose in wall cavity + 2.5" Thermax: R-29
Above-grade walls: West facing gable	Uninsulated 2 x 4 cavity, wood siding, 1/2" polyiso, vinyl siding: R-8	Cellulose in wall cavity + 1.5" Thermax: R-22.5
Above-grade walls: South-facing gable and north-facing porch wall	Uninsulated 2 x 4 cavity, wood siding, 1/2" polyiso, vinyl siding: R-8	Cellulose in wall cavity + 1" Thermax: R-18.5
Above-grade walls: Garage wall	2 x 4 cavity with fiberglass and perlite: R-10	Cellulose in wall cavity + 2.5" Thermax: R-29
Windows: First floor and finished basement windows	Vinyl, double pane, low-e glass: R-3 (R-2 clear glass on finished basement window)	No change
Windows: Single pane basement window	Single pane, steel frame: R-1	Vinyl, double pane, low-e glass: R-3
Doors	Wood: R-2 to R-3	Insulated steel/fiberglass: R-5

Material List

The materials used during the Deep Energy Retrofit were primarily Dow Building Solutions products. Dow is a partner with Snug Planet and Taitem Engineering on this series of four Deep Energy Retrofit houses for NYSERDA.

Product Description	Manufacturer	Pricing
2.5” Thermax (reflective)	Dow Building Solutions	$1.63/sf
2.5” Thermax (white facing)	Dow Building Solutions	$1.88/sf
1.5” Thermax (reflective)	Dow Building Solutions	$1.35/sf
1” Thermax	Dow Building Solutions	$0.95/sf
Powder-driven insulation fasteners	Hilti	$0.99/ea
Wind Devil 2 screws	Wind-Lock	$0.20/ea
Closed cell foam	Dow Building Solutions	$0.75/board foot
Weathermate construction tape	Dow Building Solutions	$0.13/linear foot
Foil tape	Venture Tape	$0.09/linear foot
Weathermate straight flashing 9”	Dow Building Solutions	$0.81/linear foot
Cellulose insulation	National Fiber	$11.24/25# bag
Rafter chutes	Owens Corning	$0.60/ea
One-part foam sealant	Pur-Fill	$14.50/750 ml can
Acrylic-latex caulk	DAP	$2.09/tube
Aluminum coil stock	Genesee Building Products	$0.73/square foot

West Hill Deep Energy Retrofit Costs

The combined material and labor cost involved in the implementing the above-grade wall insulation strategy at the West Hill house is $9.55/shell square foot (ssf). The cost is separated by location in the summary table below. Note that the basement floor is included in the shell square footage but was not treated. Additional work (window, door, and HVAC) was completed during the Deep Energy Retrofit, and these costs are summarized separately.

Deep Energy Retrofit – Insulation and Air Sealing Costs

		Contract: bid price for the job		Revised price: based on actual time spent	
Location	SSF	$/ssf	Total	$/ssf	Total
Attic	1325	$4.27	$5,660	$8.21	$10,880
Basement walls	1171	$6.26	$7,330	$7.57	$8,860
Basement band joist	153	$10.20	$1,560	$10.65	$1,630
Basement floor	1325	$0	$0	$0	$0
Above grade walls	1360	$16.86	$22,931	$21.74	$29,569
Total	5334		$37,481		$50,939
Average $/ssf		**$7.02**		**$9.55**	

Deep Energy Retrofit – Additional Improvements (actual cost)

Boiler	$7,155
Window	$410
Doors	$3,000
Bath fan and ERV	$1,409
Interconnected smoke alarms	$550
Building Permits	$300
Total	$12,824

Deep Energy Retrofit – Funding Sources

Homeowner contribution: GJGNY 3.49% loan	$18,909
Home Performance with Energy Star incentive	$2,101
DOW product contributions	$11,311
PON 2254 Project funds	$17,434
Homeowner out-of-pocket contribution	$550
Total	$50,305

Taitem Snug Planet Deep Energy Retrofit
West Hill Wall Costs

Wall work	Contract Amount	Contract amount per SF	Estimate of donated material	Net contract amount	Total actual	Donated material	Total actual with donated material	Net contract amount	Actual vs. projected	Actual cost/sf
Demolition	$2,700	$1.99	$0	$2,700	$2,700	$0	$2,700	$2,700	100%	$1.99
Dense pack walls	$4,770	$3.51	$0	$4,770	$5,612	$0	$5,612	$5,612	118%	$4.13
Foam board, tape, and flashing	$5,756	$4.23	$3,400	$2,356	$9,888	$3,400	$9,888	$6,488	172%	$7.27
Window and door trim	$3,715	$2.73	$0	$3,715	$3,715	$0	$3,715	$3,715	100%	$2.73
Total, no windows, doors or siding	$16,941	$12.46	$0	$13,541	$21,915	$0	$21,915	$18,515	129%	$16.11
Install siding	$5,990	$4.40	$0	$5,990	$7,654	$0	$7,654	$7,654	128%	$5.63
Total, no window or doors	$22,931	$16.86	$3,400	$19,531	$29,569	$3,400	$29,569	$26,169	129%	$21.74
Window and doors	$3,410	$2.51	$0	$3,410	$3,410	$0	$3,410	$3,410	100%	$2.51
Total including window and doors	$26,341	$19.37	$3,400	$22,941	$32,979	$3,400	$32,979	$29,579	125%	$24.25

Radon Testing

The West Hill house had an existing radon mitigation system. Radon testing was completed before and after the deep energy retrofit, and the test results are below actionable levels.

Pre-DER Radon Testing

HERE ARE YOUR RADON TEST RESULTS:

LAB ID# KIT ID#	RADON LEVEL pCi/L	TEST LOCATION	TEST PARAMETERS Start/Stop Date Time	TEST METHOD EPA-402-R-92-004
1162471 P40992	<0.9	Basement Work Bench Test Room Location: Basement Test Floor: Basement	Short Term 7/20/2012 to 7/23/2012 15:31 to 13:00	Activated Charcoal

Post-DER Radon Testing

HERE ARE YOUR RADON TEST RESULTS:

LAB ID# KIT ID#	RADON LEVEL pCi/L	TEST LOCATION	TEST PARAMETERS Start/Stop Date Time	TEST METHOD EPA-402-R-92-004
1189612 P40903	<0.6	Test Room Location: Mechanical room on work bench Test Floor: Basement	Short Term 11/27/2012 to 11/30/2012 14:40:00 to 14:46:00	Activated Charcoal

Temperature and Humidity Testing

Temperature and humidity dataloggers were installed on December 11, 2012 to measure post-DER conditions, and they were removed on January 25, 2013. The data showed stability throughout fluctuating outdoor temperatures, which extended down to minus 6°F. The monitored temperatures were lower than expected, especially with an infant in the house. The post-DER humidity levels were acceptable, even in the kitchen. No condensation was reported on the windows, and the homeowners were very impressed with their increased comfort.

Location	Average Temperature, °F	Average Humidity, RH %	Maximum Humidity, RH %
Basement wall – exterior wall of mechanical room (A)	64.48	37.61	45.56
Basement wall – interior wall (B)	64.90	36.80	44.68
Dining room – interior wall (C)	69.82	35.14	51.40
Bedroom / Office – interior wall (D)	69.75	34.47	52.75
Kitchen – interior wall (E)	69.83	35.79	61.88
Exterior – outside of basement door under porch, north facing (temp only)	31.65	n/a	n/a

Good Discoveries

The Deep Energy Retrofit at the West Hill house yielded many good discoveries during the process. The following strategies were employed in this house, and they should be considered for reducing the overall cost and increasing the accessibility of any deep energy retrofit.

1. Working with a local building materials salvage organization. Finger Lakes Re-use did the removal of the siding, trim, and old ½" foam sheathing at reasonable cost. They labeled and bundled the siding for re-installation, recycled the aluminum trim, and re-purposed the old foam sheathing. Unfortunately, some very nice cedar clapboards that were under the other layers contained lead paint and could not be re-used or re-sold.
2. Re-use existing siding. We were able to re-use the majority of the vinyl siding. Extra-wide corner boards were used to accommodate for the extra wall thickness. The result was considered acceptable by the homeowner, but the aesthetics of the re-used siding were not as good as would be expected had new siding been used.


Finger Lakes Re-Use begins removing the siding. Siding was labeled for re-installation.

3. Keeping existing windows. The windows on the main floor of this house were all double pane, low-e vinyl replacements in good condition. Keeping the existing windows in place, carefully flashing, and re-trimming them allowed us to avoid the cost of new windows.
4. A single layer of foam. Unlike some DERs that used multiple layers of foam, this study utilized a single layer. While we did not get the benefits of staggered seams, a high level of air tightness was achieved.

5. Utilize the Accu-cutter. This allowed the foam sheathing to be cut quickly and with very tight tolerances.

Using the Accucutter.

6. Utilize creative strategies to avoid extending roof overhangs. On one small gable end section, the removal of the old siding created enough space to allow a thinner layer of foam sheathing (1") without extending the roof overhangs. On two larger gable ends, a frieze board detail was extended horizontally to create a change in plane which could be flashed with z-flashing, allowing the use of 2.5" foam sheathing. Avoiding extending the roof overhangs, which would have involved both carpentry and roofing, reduced the overall cost of the project by at least \$2000. Because the majority of the wall surface had the 2.5" sheathing, the overall performance of the walls remained above R-25 (U<0.04). However, the lack of overhangs on the gable ends required extra attention to drainage plane/flashing details.

Detailing the drainage plane on the front gable end.

7. Use of thinner (1") foam on one short wall adjoining a porch allowed us to avoid changing a door opening.
8. Sweat equity. This was a somewhat mixed experience. The homeowner had initially wanted to remove the attic fiberglass himself (for a credit) but found the job overwhelming. He did take on sheet rocking a section of the basement that was gutted to allow spray foam.
9. Utilize NYSERDA/Home Performance with Energy Star financing and rebates. \$21,010 of the project cost was funded through the HPwES program. The

customer received an incentive of $2101 and financed the balance ($18,909) for 15 years at 3.49%.

10. Unleash the crew's creativity. We created a graph of the blower door numbers and updated it after each test. The crew responded with enthusiasm to the challenge of reaching the air leakage goal. They brainstormed and thought of many small air sealing details that contributed to the overall success of the air sealing.
11. Lock-top dampers. Wood burning fireplaces (rarely used in this case) are serious sites of air leakage. We documented a reduction in air leakage of approximately 200 CFM50 from the Lock-top damper alone. (The homeowner will be cautioned to open a window to provide makeup air whenever the fireplace is in use). We have begun to recommend Lock-top dampers routinely in our home performance work.
12. Integrate foam wall sheathing with exterior wall top plate air sealing and attic wind blocking.

Soffit boards were removed so the Thermax can extend up past the top plates. We notched around the rafter tails and sealed the wall/ceiling junction with spray foam from the attic.

Spray foam provides a positive seal between top plates and Thermax at the garage wall.

13. Get the attic clean. We not only removed the fiberglass batting but vacuumed the remaining debris with a gas-powered insulation vacuum. This restored the attic to a new construction-like condition which made it pleasant to work and created the best conditions for foam adhesion.
14. Take advantage of DER to upgrade safety and/or aesthetics. The clearing out of the attic provided a great opportunity to install interconnected smoke alarms. The fire separation between the garage and house/attic was also upgraded to

modern code requirements, and unsightly cable wiring was hidden behind the siding.

Time and Motion Techniques

During the Deep Energy Retrofit at the West Hill house, many techniques that were investigated and recommended during the Time and Motion Study were utilized. Some of the techniques put into practice were further revised.

1. Fastening to wood-frame walls

a) 4" Wind-Lock screws were used to attach Thermax sheathing to wood-frame walls.
b) The number of screws per sheet was reduced from the manufacturer's recommendation of 28-30 per full sheet to 12 per full sheet. This seemed to provide very secure attachment. In this house, the siding contractor decided to attach ¾" furring strips with 5" Head-lok screws over the Thermax. The Head-lok screws went directly into the studs. This was done because it was determined that the original fiberboard siding would not reliably hold siding nails; it also provided an extra-secure attachment for the Thermax.
c) Where possible, a single Wind-Lock screw was used to span the joint between two sheets of Thermax.

Thermax being installed.

Thermax installed. Note Accu-Cutter on sawhorses at right.

2. Fastening to concrete walls

a) Despite the lower installed cost of the Christmas tree fasteners, the crew expressed a strong preference for the Hilti fasteners, both because of the tighter connection to the wall and the reduced physical effort of installation. The Hilti fasteners were selected for this project and performed well. Six fasteners were used per full sheet.

Using the Hilti to attach Thermax to basement wall.

Basement wall with Thermax, not yet taped.

3. Full cuts

a) The Accu-Cutter was used for all full length cuts. Using two passes for 2.5” Thermax, it produced clean, straight, factory-like cuts, allowing pieces to be butted very tightly against each other and against the window jamb extensions. The clean rips also allowed efficient use of scrap material.

b) The siding crew (Sunnybrook Builders), which uses a table saw to cut polyiso on other jobs, expressed interest in the Accu-Cutter, commenting on the low dust generation.

4. Cross cuts and L-cuts

a) A PVC saw or a fine-toothed woodworker’s saw were used for cross cuts with good results. These tools were also used to notch around rafter tails.

b) It was determined on site that the best overall results would be obtained by avoiding L-cuts around windows and doors and instead using the Accu-cutter to create two rectangular pieces joined by a vertical seam.

5. Hole cuts

a) A keyhole saw was used for hole cuts (for example, around boiler vent pipes) with good results.

6. *Taping*

a) Weathermate construction tape with a roller applicator was used to tape seams in the exterior Thermax. Corners were taped with 9” straight flashing. No problems were reported.

Taped Thermax and window flashing on rear of house.

7. Window bucks and flashing

a) The buck and flashing approaches tested in the Time and motion were designed for new, flanged windows. The windows in this project were existing vinyl inserts which were left in place. The windows were flashed as “innies,” with wooden jamb and sill extensions built outboard of the existing window trim. Straight flashing was used to wrap the sill and sill extension. We developed a technique for slitting the release paper longitudinally which allowed us to tuck the unadhered portion of the straight flashing up under the sill angle and to adhere it to a second piece of straight flashing below. Straight flashing was also used for the side and head flashings, and a piece of Weathermate construction tape was used to protect the head flashing from low-angle shear per Building Science Corp. recommendations. The straight flashing worked well, although in a few places it was not tucked tightly into corners and interfered with installation of aluminum window trim. In future installations of this type, the straight flashing should be pressed tightly into corners with a tool that will not cut or rip the straight flashing.

Window buck.

Window buck, alternate view.

Sill extension detail.

Crew and Homeowner Comments

Crew Comments

The Snug Planet crew thoroughly enjoyed working with the West Hill homeowners during the Deep Energy Retrofit. Their willingness to fully participate in all that a deep energy retrofit entails, along with desirable house features, made this a successful project.

a) The single story house was accessible: access to attic and basement from outside the main living space.
b) Cleaning out the attic by removing old insulation made a significant impact in the quality of the attic work
c) The Thermax went up fast. Four rows of three fasteners, for a total of twelve fasteners per sheet, were used.
d) The Dow tapes were quite sticky and effective. The flexible flashing was very useful on site for a few details such as the areas around the boiler exhaust pipes.
e) The crew was very mindful of all the connections and drainage planes.
f) Next time, a preconstruction meeting will be held with all the contractors prior to starting.
g) The siding contractor should have allowed more time and people for this job, and putting the re-used siding back on was a more difficult process than expected.

Post-attic cleanout.

Homeowner Comments

The West Hill house homeowners were very pleased with the deep energy retrofit. They are exceedingly happy with the quality of the work. The great communication throughout the project was helpful so they knew what was going to happen and when. They are delighted to be able to walk around the house in bare feet without extra layers of clothing. The only downside was the extended time needed by the siding contractor to finish the siding work.