Optimized Strategy for Scaling Up Deep Energy Retrofit

Hawthorne Circle House

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Executive Summary

A Deep Energy Retrofit (DER) was successfully performed at a home at Hawthorne Circle in Ithaca, New York, during the autumn/winter of 2012-2013. This is the second DER performed for this project. The Hawthorne Circle house is a 1670 sf. ranch built circa 1950 with an unfinished basement. The scope of work for this DER included:

- Attic: Removed existing fiberglass and cellulose 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 wood siding. Extended eaves on selected portions of roofline. Performed targeted insulation with high-density cellulose to fill voids in wall cavities. Installed window bucks, flashing and trim. Installed 2.5" Thermax. Installed furring strips and fiber-cement siding.
- Basement and crawlspace walls: Installed 2.5" Thermax on basement and crawlspace walls. Installed 2" polyurethane foam on rim joists. Installed ¾" EPS insulation and vapor barrier on crawlspace floors.
- Windows and doors: Older single pane windows with aluminum storms were replaced with new, double pane, low-e vinyl windows. One older wood door was replaced with a new insulated steel door. Air sealing was performed around both new and existing windows.
- Mechanicals: A new, sealed combustion furnace and a water heater were installed. Energy Star compliant ventilation (Panasonic Whisperlite bath fan) was installed.

The results of the DER at Hawthorne Circle met the objectives of the DER program.

Program Objectives	**Goal**	**Actual**
Total envelope air leakage	< 0.25 CFM50/ssf	0.23 CFM50/ssf
Above grade wall insulation	> R-25	R-30
Labor and material costs	< $10/ssf	$6.01/ssf

Other Key Metrics	**Pre-DER**	**Post-DER**
Blower Door reading	6158 CFM50	1434 CFM50
Radon testing	1.3 pCi/L	TBD

Executive Summary in Photos

Areas of Air Leakage Reduction

The Hawthorne Circle 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 cellulose and debris with a gas-powered insulation removal vacuum.

Attic prior to start of work. Fiberglass batts and cellulose insulation totaled about 5".

Attic cleanout in progress.

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. Attic air sealing was checked by a combination of visual inspection, blower door (including zone pressure diagnostics) and infrared inspection.

The follow leaks were sealed:

a) General repairs to holes in sheetrock were performed by the general contractor. An older recessed light was removed, the sheetrock patched, and a surface-mounted fixture installed.

Holes were patched and repaired.

The ceiling plane contained some obvious air sealing opportunities.

b) 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.

c) Electrical boxes for lights and smoke alarms.

d) Plumbing stacks.

e) Bath fan housing.

f) A CMU chimney was present at the beginning of the project, extending from the basement to above the roof line. This was demolished down to the basement, and the holes in the ceiling plane were patched with sheetrock.

g) Two leaky attic access hatches were present. One was completely sealed from above. The other was replaced by a tighter-fitting, insulated hatch. The trim was caulked, and a foam gasket was installed where the hatch contacted the trim.

2. Main floor walls

A large bypass was discovered behind a bath tub on an exterior wall. A new one-piece tub was installed as part of the bathroom remodel. Sheathing was removed so that the tub could be installed from the exterior. The wall cavity was enclosed with new plywood on the interior and exterior surfaces, and the cavity was dense packed.

Smaller leaks were associated with gaps in the sheathing, electrical penetrations, and a range hood vent. Wall cavities were mostly full of old urea formaldehyde foam insulation, which had shrunk and cracked, leaving voids toward the tops of many wall cavities. Voids were estimated at ~8% of total wall area. Voids were identified with infrared scanner and dense-packed with cellulose insulation.

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

The conditioned main floor of the house contained a mix of old, single pane windows with aluminum storms and newer, double-pane replacement windows. The older windows were replaced with new, double-pane vinyl replacement windows; windows were sealed with one-part foam and caulk. For the double pane windows than were not replaced, interior trim was removed, and gaps between the window jambs and rough framing were sealed with foam and caulk.

The original wood back door was leaky and was replaced by a new, tightly sealing steel door. The solid wood front door was kept and will have a new threshold and weatherstripping installed toward the end of the interior finish work.

4. Basement/crawlspace sill plate and band joist

The basement band joist/sill plate assembly consisted of wood 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 wiring and other 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.

5. Crawlspace access and vents

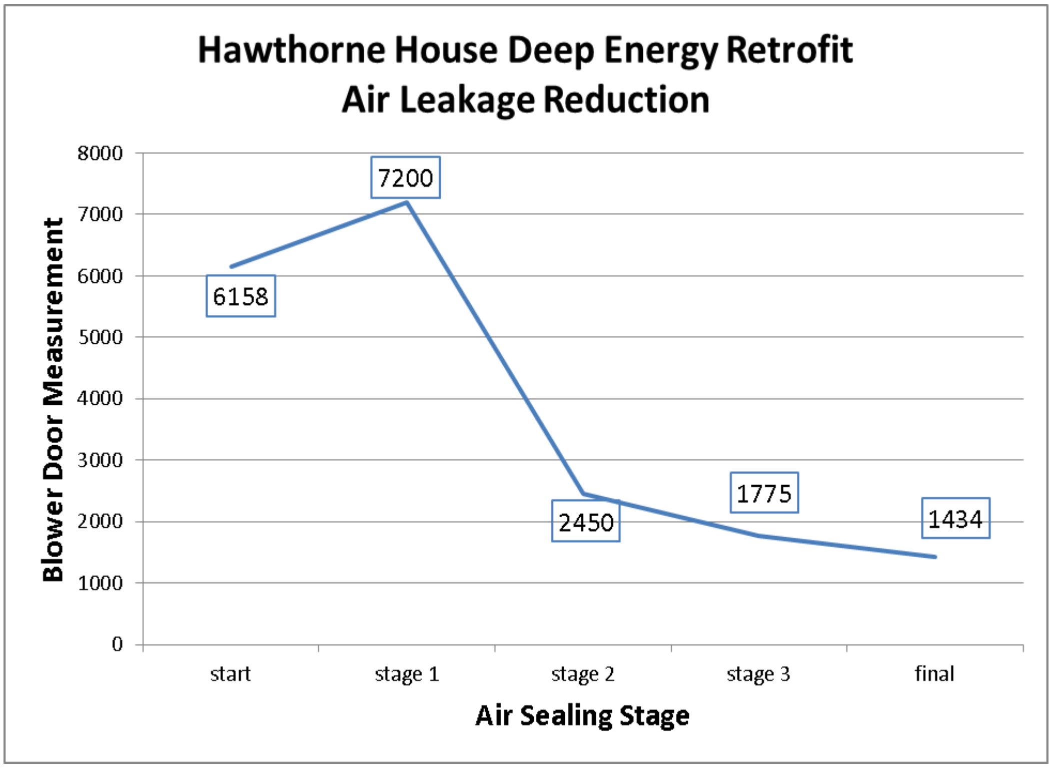
The extremely leaky crawlspace access panel was temporarily replaced by a piece of 2.5" Thermax and will ultimately be replaced by a tight-fitting, weatherstripped wood access panel.

Each of the two crawlspaces contained metal crawlspace vents. These were replaced by CMU blocks, mortared in place.

Metal crawlspace vents were replaced with CMU blocks.

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	6158	
Stage 1	7200	• Attic insulation removed • Siding removed
Stage 2	2450	• Windows and back door replaced • Above grade walls dense packed and foam board attached • Crawlspace vents sealed • Crawlspace and basement walls insulated • Band joist insulated • Damaged sheetrock repaired.
Stage 3	1775	• Attic air sealing (top plates, etc.)
Final	1434	• Blower door/infrared guided air sealing, mainly of window and door openings

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	3" fiberglass batts, 2" cellulose: R-18	Cellulose: R-60
Basement walls	Uninsulated block: R-2	2.5" Thermax + block: R-18
Crawlspace walls	Uninsulated block: R-2	2.5" Thermax + block: R-18
Basement/crawlspace band joist	Uninsulated band joist: R-3	2" closed cell foam + 2.5" Thermax: R-31
Crawlspace floor	Dirt floor with 6 mil vapor barrier: R-0	¾" EPS, 20 mil vapor barrier: R-3
Above-grade walls: Most walls	2 x 4 wall, Urea formaldehyde insulation with ~8% voids: R-12	Voids in UFFI filled with cellulose; exterior sheathing of 2.5" Thermax: R-30
Windows: Existing double pane windows	Vinyl, double pane, low-e glass: R-3	No change
Windows: Single pane windows on first floor	Single pane clear glass, wood frames with aluminum storm windows: R-2	Vinyl, double pane, low-e glass: R-3
Windows: Single pane basement window	Single pane, steel frame: R-1	No change
Back door	Wood: R-2 to R-3	Insulated steel/fiberglass: R-5
Front door	Wood: R-2 to R-3	No change

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
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
TerraBlock (crawlspace floor insulation)	Basement Systems	$0.45/sf
CleanSpace crawlspace liner	Basement Systems	$0.33/sf

Hawthorne Deep Energy Retrofit Costs

The combined material and labor cost involved in the implementing the above-grade wall insulation strategy at the Hawthorne Circle house is $6.01/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, heating, and fan) was completed during the Deep Energy Retrofit, and these costs are summarized separately. With the additional improvements of windows, heating, and fan, the cost was $9.63/ssf.

Deep Energy Retrofit – Insulation and Air Sealing Costs

		Contract price for the job Revised with actual costs	
Location	SSF	$/ssf	Total
Attic	1671	$3.67	$6,140
Basement/crawl walls	812	$6.21	$5,041
Basement band joist	196	$5.26	$1,030
Crawlspace floor	886	$4.00	$3,544
Basement floor	784	$0.00	$0
Above grade walls, including roof extensions	1532	$12.85	$19,681
	5881	$6.01	$35,345

Deep Energy Retrofit – Additional Improvements

Furnace and ductwork	$14,012
Windows and doors	$9,033
Bath fan	$500
Misc. repairs, non-energy related	$53,472
Total, including DER and additional work	$110,116

Total energy related envelope work	$33,099	$5.62/ssf
Total energy work including windows, heating, and fan	$56,645	$9.63/ssf

Deep Energy Retrofit – Funding Sources

Ithaca Neighborhood Housing construction funds	$89,273
DOW product contributions	$5694
PON 2254 Project funds	$15,150
Total	$110,116

Taitem Snug Planet Deep Energy Retrofit
Hawthorne 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	$815	$0.53	$0	$815	$815	$0	$815	$815	100%	$0.53
Targeted dense-pack	$3,510	$2.29	$0	$3,510	$1,336	$0	$1,336	$1,336	38%	$0.87
Foam board, tape, and flashing	$3,246	$2.12	$3,246	$0	7666	$3,246	7666	7666	236%	$5.00
Total, no windows, doors or siding	$7,571	$4.94	$3,246	$4,325	$9,817	$3,246	$9,817	$9,817	130%	$6.41
Install siding	$9,864	$6.44	$0	$9,864	$9,864	$0	$0	$9,864	100%	$6.44
Total, no windows or door	$17,435	$11.38	$3,246	$14,189	$19,681	$3,246	$9,817	$19,681	113%	$12.85
Windows and door	$9,033	$5.90	$0	$9,033	$9,033	$0	$0	$9,033	100%	$5.90
Total including windows and door	$26,468	$17.28	$3,246	$23,222	$28,714	$3,246	$9,817	$28,714	108%	$18.74

Radon Testing

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
1160683 P40977	**1.3**	Test Room Location: bsmt near furnace Test Floor: Basement	Short Term 7-13-2012 to 7-16-2012 11:05 to 10:05	Activated Charcoal

Post-DER Radon Testing

Radon testing is scheduled, and this section will be updated.

Temperature and Humidity Testing

Temperature and humidity data loggers will be installed to measure post-DER conditions. Homeowners will not be moved in for optimal data collection this winter; therefore temperature and humidity testing will occur next winter.

Good Discoveries

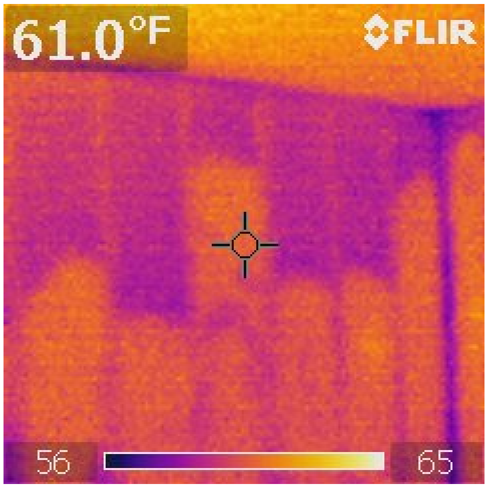
The Deep Energy Retrofit at the Hawthorne Circle house yielded many good discoveries during the process. The following strategies were employed in this house, and they should be considered for reducing the overall cost and increasing the accessibility of any deep energy retrofit.

New findings:

1. Piggybacking a deep energy retrofit onto a major exterior rehab reduces costs. The Hawthorne Circle house was purchased by Ithaca Neighborhood Housing in dilapidated condition with the intention of rehabbing the house and selling it to a low or moderate income family. Roof, siding, window and door replacement were planned anyway. While the cost of the new siding is included in the price per shell square foot, the incremental cost of going from a conventional rehab to full DER was actually less. The fact that the house was vacant during the work made access easier, and reduced the need for daily cleanup of work areas.

Nearly ready for siding.

2. Existing cavity insulation limits the effectiveness of dense pack cellulose as an air leakage reduction method. While the Hawthorne Circle house met the DER air tightness goals, the CFM50/SSF was considerably higher than for the West Hill House. A large part of the difference appears to relate to the fact that for the West Hill project, we started with cavities partially full of aged UFFI insulation. The dense pack was able to seal the large voids and some of the smaller channels in the UFFI; however, we believe that the overall result was not as good as if we had started with empty cavities.



Infrared image of walls prior to insulating.

3. Working with a well organized construction manager and general contractor reduces delays and increases efficiency. The Hawthorne Circle project was delayed because the general contractor and his subs (particularly the electrician) were slow to complete their work. Communication around scheduling was often challenging. Our crew could have worked much more efficiently if other components of the project had kept on schedule.

4. Crawlspace floors can be treated cost-effectively to provide vapor management and increase R value. Our approach does not include insulation of concrete slabs below grade; energy modeling indicated that this measure provides only tiny energy savings at considerable cost. However, dirt-floor crawlspaces can be treated at more modest cost. A well-sealed vapor barrier is required over the soil for radon and moisture control. A flexible EPS floor insulation was installed under the vapor barrier. Because the crawlspace floor is closer to grade than the basement floor, the insulation of these surfaces has a greater impact on comfort and energy use.


Vented crawlspace with inadequate vapor barrier.

Confirmation of findings from West Hill house:

1. Working with a local building materials salvage organization is a sound strategy. As at the West Hill house, Finger Lakes Re-use did the removal of the siding and trim and cleanout of the crawlspaces. Finger Lakes Re-use did an extremely professional job at reasonable cost. While the siding could not be re-purposed, some interior plumbing fixtures were sold.

2. Keeping existing windows can reduce costs. As in the West Hill project, existing double pane windows in good condition were kept, reducing the overall cost of the project.

3. A single layer of foam reduces costs. Unlike some DERs that used multiple layers of foam, this study utilized a single layer.

4. The Accu-cutter allows the foam sheathing to be cut quickly and with very tight tolerances.

5. Foam wall sheathing can be integrated with exterior wall top plate air sealing and attic wind blocking.

Notching foam sheathing to fit around rafter tails.

6. Getting the attic clean is critical. As with the West Hill project, a gas-powered vacuum was used to clean the attic prior to air sealing. This was even more important at Hawthorne Circle, where loose cellulose insulation was present in the attic.

7. Take advantage of DER to upgrade safety, repair problems and/or aesthetics. Extensive rot on exterior wall framing and sheathing was repaired during the project. Smoke alarms were installed, heating and hot water were converted to sealed combustion, and vapor/radon control in the crawlspaces was improved.

Time and Motion Techniques

During the Deep Energy Retrofit at the Hawthorne Circle 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" Ci-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 in order to provide a vented air space behind the fiber-cement siding. it also provided an extra-secure attachment for the Thermax.

c) Where possible, a single Ci-lock screw was used to span the joint between two sheets of Thermax.

Thermax installation in progress. Rotten fiberboard sheathing was replaced by plywood.

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. This was especially valued in the restricted environment of the crawlspaces. The Hilti fasteners were selected for this project and performed well. Six fasteners were used per full sheet.

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.

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 furnace 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.

7. Window bucks and flashing

a) The buck and flashing approaches tested in the time and motion studies were designed for new, flanged windows. The windows in this project were a mix of existing wood/vinyl inserts, which were left in place and new, unflanged vinyl windows, which were installed as inserts to match the style of the existing windows. Bucks, including sill extensions, were built of 2x framing lumber. Aluminum coil stock was bent on a brake to provide an impermeable sill flashing. After the foam sheathing was installed, straight flashing was used to span the joints between the foam and the buck, and between the buck and the window. The flashing was covered with fibercement stops and casings. 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 the general contractor complained that it was very hard to remove residue if the flashing extended too far onto the vinyl windows and had to be trimmed back after the fibercement stops were installed.

Window bucks. Note the aluminum flashing covering the sill.

Installing Weathermate tape to protect the head flashing from low-angle shear.

Crew Comments

The Snug Planet crew thought that the deep energy retrofit at Hawthorne Circle went quite well. There were merits to working in a vacant house, such as less daily cleanup was required. Working with a general contractor who was not fully on board with the DER concept resulted in timing and preparation issues. The Hawthorne Circle house proceeded in a more piecemeal schedule than would have been preferred.

The crew enjoyed putting up the Thermax, and they felt it went very smoothly. They feel more confident in their techniques, and they will keep improving. The crew is developing strategic approaches when encountering different types of existing conditions, and these will be applied to the next two deep energy retrofits for this project, as well as their non-DER work.

A large sign showcases the work in progress.