Home Innovation RESEARCH LABS™

Deep Energy Envelope Upgrades Using Retrofit Insulated Panels

Prepared For

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New York State Energy
Research & Development Authority
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Albany, NY 12203

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TABLE OF CONTENTS

Figures

Tables

Glossary of Abbreviations

AHA	Albany Housing Authority
ASTM	American Society for Testing and Materials
Albany-CAP	Albany Community Action Partnership
CFM	Cubic feet per minute
CFM50	Cubic feet per minute at 50 pascals of depressurization
CMU	Concrete masonry unit
DER	Deep energy retrofit
DP	Dewpoint
EE	Energy efficiency
EPS	Expanded polystyrene
GE-EPS	Graphite enhanced expanded polystyrene
GWP	Global warming potential
HDD	Heating degree days
HFC	Hydrofluorocarbon
MC	Moisture content
NY	New York
NYSERDA	New York State Research and Development Authority
OSB	Oriented strand board
RH	Relative humidity
SIPA	Structural Insulated Panel Association
SPF	Spray polyurethane foam
SPF_{CC}	Spray polyurethane foam, closed cell
SSF	Shell square feet
XPS	Extruded polystyrene

EXECUTIVE SUMMARY

The Albany Housing Authority provides rental housing for very low, low, and moderate income households in the city of Albany and participated in this deep energy retrofit project in the 145-unit Capital Woods neighborhood. The site is a multi-family building of seven two-, three-, and five-bedroom units in Climate Zone 5.

Home Innovation Research Labs teamed with NYSERDA and the Structural Insulated Panel Association to perform a deep energy retrofit of the building using a retrofit insulated panel product composed of 4x8 foot panels of expanded polystyrene and one face of oriented strand board (OSB). Panels are applied to the exterior of the building with screw fasteners that extend through the panel to the structural frame of the building. Cladding is attached to the OSB face of the panel with a weather resistant barrier between the two. Table 1 shows the project goals and actual results with the completion of Phase I. Phase II is a placeholder for AHA's implementation of an equipment upgrade when resources of approximately $30,000 become available.

Table 1. Recap of Project Goals and Actual Achievements

Target	Project Goals	Actual Results Phase I	Projected Results Phase II
Opaque Wall R-value (weighted)	R-25	R-27	R-27
Air Seal, CFM50	3,968	9,435	9,435*
Cost, $/SSF	< $10.00	$8.87	$11.49
Energy Savings (Heat & Hot Water)	30%	14%	39%

*Simulations were completed using this number. In fact, AHA will attempt to mitigate this prior to the equipment upgrade.

The project is a monetary success at a total cost of $8.87 per shell square foot of affected area. The opaque wall R-value goal of R-25 was surpassed.

The energy savings shortfall may never be controllable in this building, as is, which is discussed in detail within the report. The activities that were undertaken to arrive at this level of energy savings have been valuable in advising Albany Housing Authority of the options and outcomes that can be expected of various actions to enhance the energy savings in the eighteen other buildings at the site. In fact, this Capitol Woods community presents an ideal test site for additional research and development into affordable energy conservation measures.

Retrofit insulated panels were competently installed on this 2- to 3-story building by a three-person siding installation crew, proving the constructability of the product with minimum training. Insufficient air leakage sealing results, however, indicate that either the walls are not this building's primary leakage pathway or the product is not a two-fold (thermal and air seal) solution.

BACKGROUND AND INTRODUCTION

The New York State Energy Research and Development Authority's (NYSERDA) promotion of additional research into materials and methods to achieve highly insulated walls and an air sealed building shell led the Home Innovation Research Labs (Home Innovation) and the Structural Insulated Panel Association (SIPA) to form a partnership to investigate the constructability and performance of a product called retrofit insulated, or "nailbase," panels, Figure 1.

Figure 1. Six-inch Retrofit Insulating Panels

Project goals were to identify a residential building that was eligible for participation and develop a repeatable strategy to insulate the building envelope to include a minimum of R-25 opaque above-grade walls and to improve whole building air leakage to rival .25 CFM50 per shell square foot after retrofit. Retrofit cost to achieve these results was not to exceed $10 per shell square foot. The demonstration site search process took approximately eighteen months, during which a seven unit multi-family building was identified as a candidate. (See Appendix E for additional information on the site discovery process.)

The Albany Housing Authority (AHA) which provides rental housing for very low, low, and moderate income households in the city of Albany together with its general partner provided the site for the deep energy retrofit (DER) project in the 145-unit Capital Woods neighborhood. A multi-family building of seven two-, three-, and five-bedroom units was selected as the site for the DER demonstration project covered in this report.

The DER is located in downtown Albany NY, Climate Zone 5, with an average of 6,438 heating degree days (HDD) per year, Figure 2.[1] The project was envisioned as a two-phased activity beginning with a building envelope upgrade, and followed, within a two- to five-year timeframe, with a replacement of heat and hot water equipment.

[1] www.nyserda.ny.gov/Cleantech-and-Innovation/EA-Reports-and-Studies/Weather-Data/Monthly-Cooling-and-Heating-Degree-Day-Data

Condensation Potential – 150A & 150BCondensation Potential – 150A & 150B

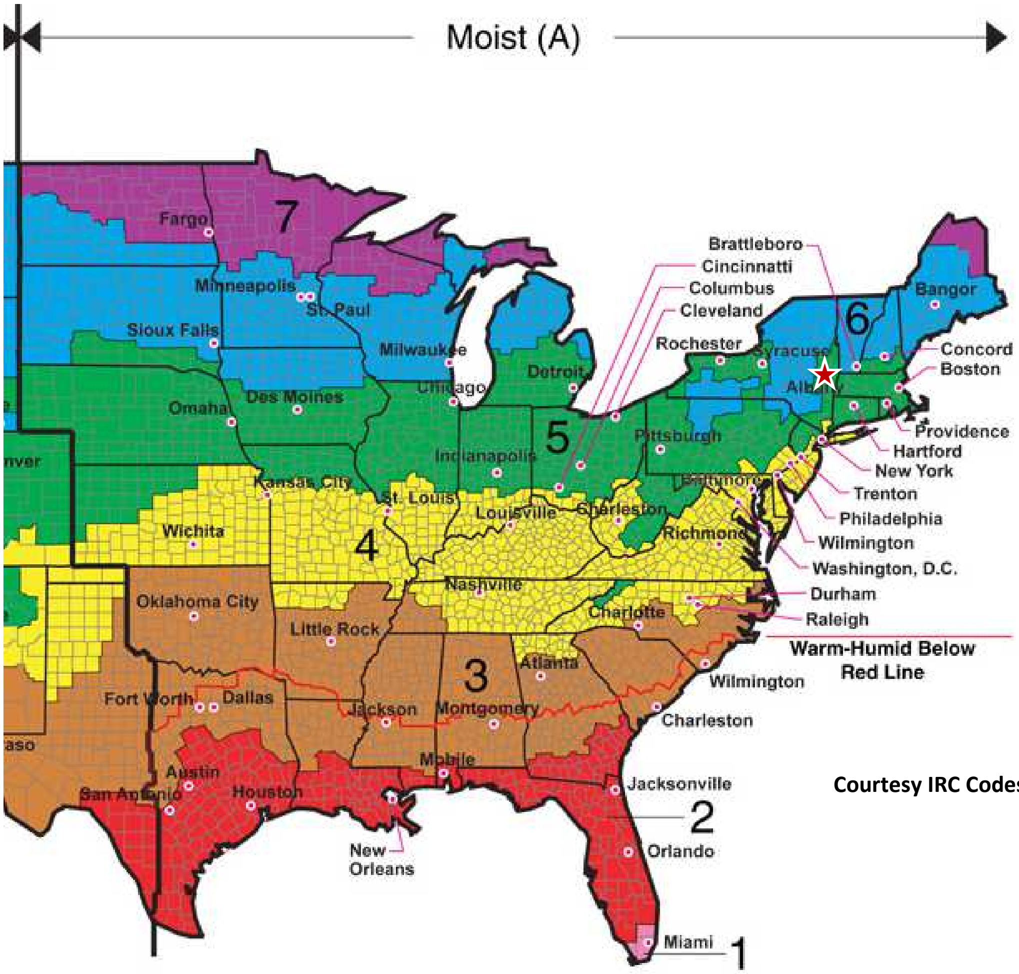

Figure 2. Albany NY Located on Climate Zone Map

PRE-RETROFIT SPECIFICATIONS

The roughly 112 ft x 31 ft building consists of seven single floor apartments clustered in rowhouse-like configurations of two-story buildings which are separated by 8 inch concrete masonry unit (CMU) firewalls. The building's foundation is an in-ground basement at the front that daylights in the rear. All units can be accessed by individual exterior doors from the front and rear of the building and there are no common areas in the buildings. The heated basements are inaccessible to tenants and house the power vented boilers and water heaters. Building sections which are separated by the continuous CMU walls have a split-faced texture where the exterior walls are offset and visible (Figure 3 and Figure 4).

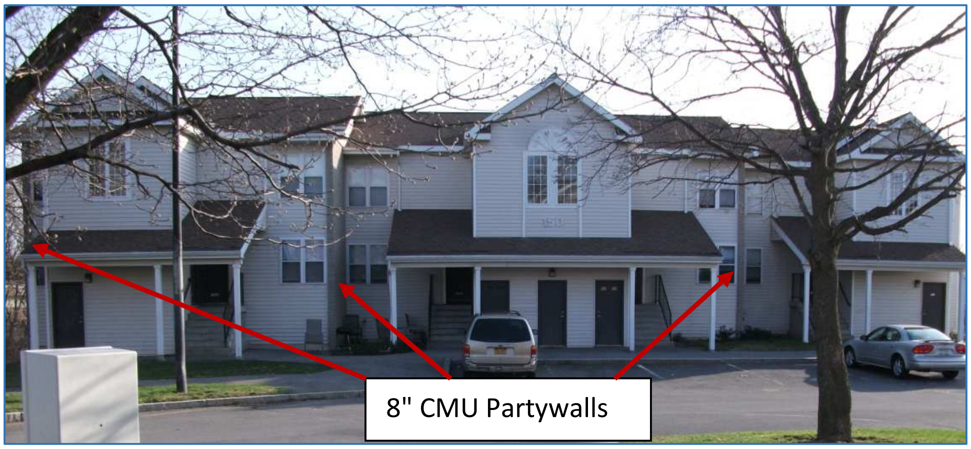

Figure 3. Front Elevation (southwest), 150 Lark

Figure 4. Rear Elevation (northeast), 150 Lark

The apartments which had been located in the basement were abandoned in a 1998 revitalization of the building. Walls are of 2x4 wood frame construction with R-11 or R-13 kraft-faced fiberglass batt insulation. During the 1998 revitalization flat roofs were covered over with pitched roof trusses and a new composite shingle vented roof was constructed. At the same time, bathroom ceiling fans were installed with sealed ducting vented to the outside through the new attic space, Figure 5. The CMU firewalls terminate at the attic floor.

Figure 5. Typical Attic at East End of Building

The building appears to have been originally constructed in the 1970s. During the revitalization, the rear door and window openings to the abandoned basement apartments were framed in, sheathed with OSB on the exterior and finished with fiberglass batt insulation with a foil scrim face on the inside. Some of the interior frame basement walls were removed to promote air flow and discourage mold formation. The basements are heated to keep water heaters, two boilers, pump, and sprinkler system pipes from freezing. The whole building's conditioned area covers approximately 10,416 square feet of space. Heat is supplied to the basement via the hydronic system that originally supplied the basement apartments with heat. Four-inch PVC piping extending through the exterior rear wall provides combustion air at the water heater locations and water heaters are power vented. (Figure 6.)

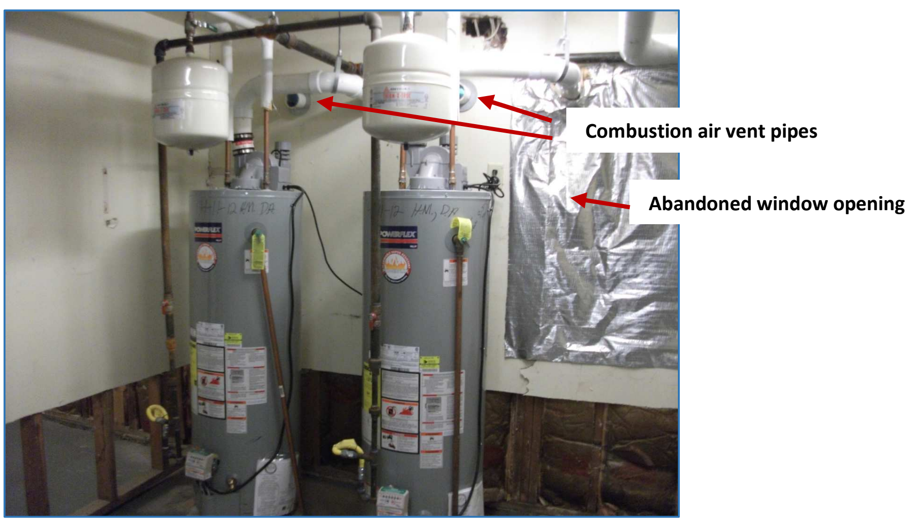

Figure 6. Typical Water Heater Installation for Two or Three Apartments

Central building meters supply the heat, water heat, and building basement and exterior security lighting. Each individual apartment is serviced with its own electric meter and all electric appliances. Hookups for washing machine and dryer are only provided in the one five-bedroom apartment (152A) and metered to that unit. The other six apartments do not enjoy a provision for in-building laundering.

Capitol Woods, the site of this demonstration project, is owned by a limited partnership that includes AHA. The general partner that manages the site was not included in the decision-making process for this project and has only acted as a stakeholder in this DER effort to the extent of providing notification to the tenants, access to the units, and providing company personnel during unit entry. Maintenance and equipment replacement schedules were not communicated or disclosed after the fact. Site inspections provided the opportunity to discover maintenance activities which had been implemented within the building, such as, the removal of weather stripping on one of the front doors and water heater replacement throughout the building.

Installation of temperature limiters on in-unit hydronic controls was considered and rejected due to AHA's past history with occupant complaints on projects where heat regulating measures had been employed and later removed due to excessive tenant complaints.

THE STRATEGY

Labor Savings and Duality of Purpose

A key cost reduction strategy to this demonstration project was the intention to use less labor for repetitive trips around the building to affix multiple layers of rigid foam, cladding attachment strapping, weather barrier, and cladding than previous demonstration projects have reported;[2] particularly because the building selected as the demonstration site is 112 feet in length and covers uneven terrain. The building is also three-stories high in the rear. The OSB outer surface of the retrofit insulated panel was to serve the dual purpose of providing both an air sealing surface and a nailing surface for cladding.

Another goal was to introduce a product to both homeowners and home improvement contractors that would provide a simple, definitive, estimable component to add energy efficiency (EE) and complement a planned improvement retrofit in a two-for-the-price-of-one approach to aesthetics and efficiency. Because marketability of EE upgrades has historically been more successful when the thermal resistance material's installation coincides with a pre-existing plan to install a new building façade or roofing, the retrofit insulated panel component approach appeared to be the most affordable and reasonable path to the EE piece of a retrofit such as that performed at this demonstration site.

Modern Expanded Polystyrene

Despite anecdotal reports of some shortcomings of expanded polystyrene foam over time[3], graphite enhanced expanded polystyrene (GE-EPS) was selected for use on this project for its low global warming potential (GWP) and affordability. When GE-EPS is compared to other rigid foams like extruded polystyrene (XPS) and closed cell spray polyurethane foams (SPF_{CC}) which are blown with hydrofluorocarbons (HFCs), the pentanes used to expand EPS have significantly lower GWP than HFCs. (Pentanes, the blowing agent used to expand polystyrene beads in EPS, polyisocyanurate, and open cell

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[2] Holladay, Martin in Green Building Advisor, 2012. *The High Cost of Energy Retrofits* www.greenbuildingadvisor.com/blogs/dept/musings/high-cost-deep-energy-retrofits

[3] Lstiburek, J. for *Fine Homebuilding*, Feb./Mar. 2012. Foam Shrinks and Other Lessons, www.buildingscience.com/documents/published-articles/pa-foam-shrinks

spray polyurethane foams have a GWP of <25, whereas XPS and SPF_{CC} have a GWP in the 725 - 3,200 range, dependent on type of HFC used.)[4]

Graphite, the material that colors the EPS gray, provides lower thermal conductivity per thickness than conventional EPS resulting in a thermal resistance of R-4.5 per inch (ASTM C578 test value at 75°).[5] The thermal resistance of GE-EPS is within 10% of that of XPS at a lesser cost and GWP. Neopor®, the graphite enhanced EPS that was used on this demonstration project, claims 50% lower material use than conventional EPS[6] and the improved elasticity of Neopor can also improve sound insulation. The product's permeance is reported to be 3.5 perms at one-inch which tends to decrease by approximately half for each additional inch of thickness.[7] At the thicknesses of 3.5 in. and 5.5 in. that were used on the building, the EPS approaches the permeability of a Class II vapor barrier which restricts the movement of water vapor through the wall.[8]

Monitor Conditions within Wall Assemblies

The scope of this assessment included installation of remote temperature, relative humidity (RH) and wood moisture content (MC) sensors within the units and in the wall cavities of the building. Figure 7 shows a sensor installed in the building's existing 2x4 frame. Sensors installed in the wall cavities were attached to the original wall sheathing and record the temperature and relative humidity at the location, as well as, the moisture content of the sheathing of the original wall from within its cavity. Following the addition of the retrofit panels, these sensors were left in place to record changes in interior wall cavity measurements. A set of sensors were also installed within the retrofit panels before these were attached to the existing building. Sensors were placed in the locations identified in Table 2. Analysis of the sensor data is presented later in this report under *Results – Building Moisture Levels*.

Figure 7. Sensor Fastened within Existing Wall Cavity Via Hole Cored in Drywall

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[4] EPA, Feb., 2011. *Transitioning to Low GWP Alternatives in Building/Construction Foams*. www.epa.gov/ozone/downloads/EPA_HFC_ConstFoam.pdf

[5] ICC. *ICC-ES Evaluation Report ESR-2784*. www.icc-es.org/Reports/pdf_files/ESR-2784.pdf, accessed 4/14/14.

[6] BASF. *Building and Modernizing with Neopor®*. www.plasticsportal.net/wa/plasticsEU~en_GB/function/conversions:/publish/common/upload/foams/Neopor_Building_and_modernising_with_Neopor_EN.pdf, accessed 4/17/14.

[7] Bailes, Allison, Aug. 2013. *Graphite in Insulation — Better R-Value but Can You Write with It?* www.energyvanguard.com/blog-building-science-HERS-BPI/bid/70376/Graphite-in-Insulation-Better-R-Value-but-Can-You-Write-with-It

[8] BASF. *Neopor Innovation with Insulation.* www.neopor.basf.us/files/pdf/wall.pdf

Table 2. Sensor Locations

Sensor #	Unit #	Location	In 2x4 Wall	In Nailbase Panel
195500A1	150A Basement	Conditioned		
169602AF	150A	Conditioned		
16960211*	150B	Conditioned		
0D120242	150B	Conditioned		
169603D7	151A	Conditioned		
169603C4	152A Basement	Conditioned		
1696038B	152A	Conditioned		
16960351	152B	Conditioned		
169603F6	153A Basement	Conditioned		
1696034B	153A	Conditioned		
1696015E	153B	Conditioned		
169603EC	150A	Northeast	1st level rear	
169601BE	150A	Southwest	1st level front	
169602B3	150B	Northeast	2nd level rear	
1955016D	150B	Northeast		2nd level rear
169602CC	150B	Southwest	2nd level front	
1955008C	150B	Southwest		2nd level front
169603C9	151A	Northeast	2nd level rear	
169601A1	151A	Southwest	2nd level front	
19550149	151A	Southwest		2nd level front
16960395	152A	Southwest	Weather Station	
16960259	152A	Northeast	1st level rear	
16960298	152A	Southwest	1st level front	
16960247	152B	Northeast	2nd level rear	
195500DC	152B	Northeast		2nd level rear
169601AF	152B	Southwest	2nd level front	
19550109	152B	Southwest		2nd level front
16960309	153A	Northeast	1st level rear	
169602A2	153A	Southwest	1st level front	
16960208	153B	Northeast	2nd level rear	
195500F6	153B	Northeast		2nd level rear
169602D1	153B	Southwest	2nd level front	

*Stopped transmitting. Replaced on 3/10/15 with 0D120242

PLANNING

The retrofit insulated panel product is essentially a single layer of 7/16 in. OSB sheathing that is factory-adhered to EPS billets that have been manufactured in custom thicknesses. In the field, the panels are attached to the framework of a building from the exterior using long screws which extend through the OSB face of the retrofit insulated panel, through the EPS core and into the structural framing of the existing wall, in a prescribed pattern that is engineered to support the weight of the panel and the cladding that will be affixed to the OSB face of the panel. (See Appendix B for the Engineer's calculation of the fastening schedule for this project.)

Retrofit insulated panel to panel connections include double beads of mastic or spray polyurethane foam (SPF) for air tightness at the panel edges. Panel edges at building outside corners and soffits are "sealed" with dimensional lumber that is recessed into a foam cutout, adhered to the foam and OSB, and nailed in place through the OSB lip, Figure 8 and Figure 9.

Figure 8. West Northwest Exposure, Left Side Elevation

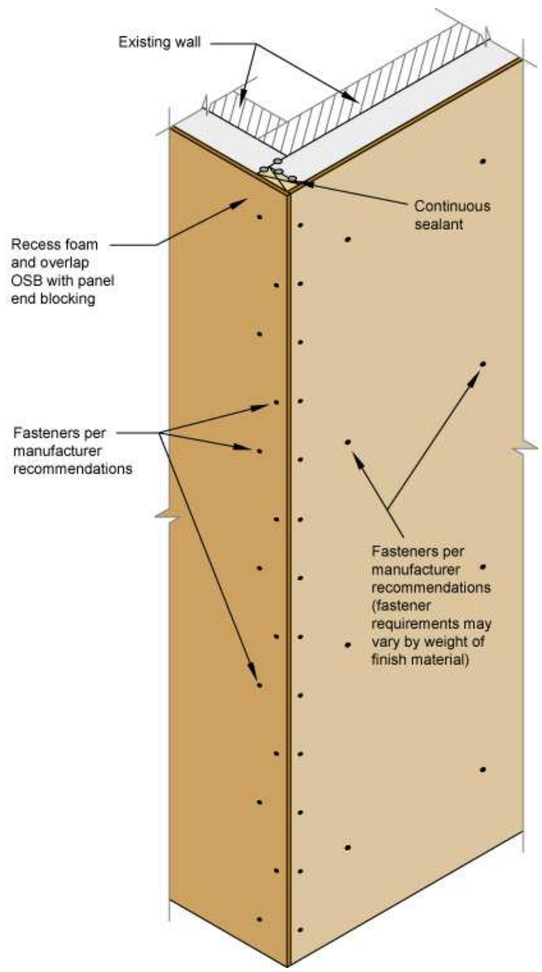

Figure 9. Typical Outside Corner Detail from Builder's Guide

In order to provide a work plan for the building, a set of blueprints were drawn up showing the location of 2 in., 4 in., and 6 in. retrofit panels, Appendix A. SIPA and Home Innovation drew up the draft *Retrofit*

Wall and Roof Panel Installation Guide (Installation Guide) to assist the trades in using the product and accessories. The Installation Guide is considered a beta version, as a SIPA task force is providing oversight for review, reformat, and update through the end of 2015.[9]

EXECUTION

The ideal installation situation would leave the old siding and water resistant barrier (WRB) in place on each wall until that wall was to receive retrofit panels. However, in order to recognize economies of scale, the contractor removed and discarded all of the existing vinyl siding as a first step. The WRB from the 1998 build was left in place as building protection while the retrofit panels were being installed (spanning a two month period). Research into the WRB's manufacturer indicated that the material's permeability rating was approximately 10.5 perms, which allows much greater vapor movement through the wall than the newly-installed nailbase panels were rated, thus, the existing WRB could be permanently left in place between the existing wall assembly and the retrofit panel assembly.

Orientation and training provided by SIPA predated project startup by eight weeks and, thus workers had forgotten some of the basic installation tips. (The sequencing consisted of a pre-bid information session in June, training in September, and start-up in late November.) The typical crew was composed of three men with specialties in vinyl siding installation and carpentry – lead carpenter, carpenter, and a sawyer (carpenter's helper). Approximately every third day, a roving crew superintendent would assign a fourth person to the crew for the day. The fourth person typically had the skills of a carpenter's helper and was not consistently the same person. The crew size handicapped the team from establishing a pace that would allow continuous application of wall panels, as the preferred installation team size would have allowed a cutter at the saw horses continuously, a roaming person feeding material to the sawyer and installers, and a two person installation team for the panel installation to run smoothly. The 4'x8'x6" retrofit insulated panels weigh approximately 64 pounds, so it was typical to have one person holding the panel in place while the other tacked it in place with screws at corners after which the two-man team worked on filling in the field with fasteners as per the schedule of 24 in. on center spacing for 4 in. panels and 16 in. o.c. for 6 in. panels (Appendix B). Due to the fact that the panels are secured to the existing framing which consisted of 2x4s at 16 in. o.c., all panels were installed at 16 in. horizontal spacing with the vertical fastener spacing varying with the engineered schedule.

At times the thick panels required some persuasion to remove a bow that had developed in mid-span. Two-thirds of the initial installation work was staged from the two-person-sized bucket of a man-lift machine. When the three-person team was present the bucket went up and down for every panel that was installed. When four people were on site a panel was transported on the deck of the bucket and subsequent panels were fed to the two in the bucket off an adjacent ladder or stairway, Figure 10. The latter procedure allowed the establishment of a rhythmic process.

[9] Structural Insulated Panel Association. www.sips.org/downloads/DRAFT%20Nailbase%20Installation%20Guide%204-8-14.pdf

Figure 10. Typical Installation

A time study was implemented for a brief period of the morning on the third day after the project started. In three and one half hours, a team of four set up the equipment and installed four 4'x9'x6" panels. The pace equates to installation of approximately 1/3 of a panel per hour per team member. The pace corresponded with that which was consistently observed throughout the progress of this project - approximately eight to ten panels installed per day. Overall, based on the payrolls, observation, and the average crew size of three people, the average number of panels installed per person per eight-hour day over the span of this project’s duration was 4.5 panels. Anecdotal information suggests that the pace is off typical expectations by a factor of at least four times.[10] The combination of seasonably cold weather, including typical wind gusts of 16 mph or higher and monthly snow accumulations above 10 in., coupled with the use of a man-lift and/or pump jacks and scaffolding to reach 52% of the work surface is partially blamed for the low productivity associated with the retrofit insulated panel installation on this project.

The wall work was performed under a fixed price contract, thus technically, the cost of the job was not affected by the pace of the workers. Panel installation commenced in December 2013 and was completed by the end of January 2014. The siding was installed over the following six weeks. Post retrofit panel installation building diagnostics did not show an air seal improvement to the building. The project’s timeline is shown in Table 3.

[10] SIPA trainers estimated 4'x8'x4" panel installation at the rate of one per 20 minutes for a two-person team.

Table 3. Timeline for Albany Housing Authority Retrofit

	2013										2014												2015			
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
DSA with AHA signed	■																									
Audit & Blower Door Test		■																								
Pre-Bid Meeting				■																						
Request for Bids							■																			
Bid Award							■																			
SIPA Training								■																		
Install Retrofit Panels										■	■															
Install Siding												■	■													
Post Wall Retrofit Blower Door Test														■												
Albany Cap Attic Seal & Insulation & Ventilation																							■			
Post Wall & Ceiling Retrofit Blower Door Test																									■	
Final Report																										■

Details That Worked

Twinned windows were removed from the exterior as one piece and set aside. A 2x6 box frame was installed directly to the existing window frame with seven and one-half inch SIPs screws inserted into predrilled holes in the 2x6s. These window jamb extensions also served as the retrofit panel edge blocking. The edge foam in the retrofit panels was then cut out to accommodate the 1-½ inch thickness of the window frame's lumber, adhered around the frame, and the OSB that overlapped the frame was secured to the edge of the 2x6 window box with framing nails. Figure 11 shows the installed window frame.

Figure 11. Window Jamb Extensions Were Formed with 2x6s Applied from the Exterior

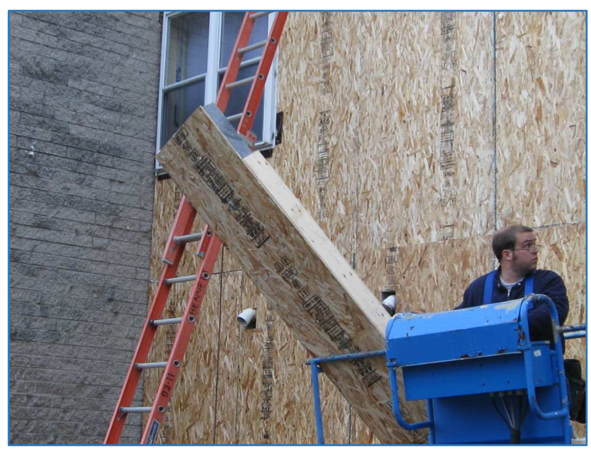

Figure 12. Transporting a Partial Edge-sealed Retrofit Panel

The 2x6 abutting the CMU wall was allowed to run wild above the window frame to serve as the edge seal on the panel that would be installed above the window. The edge sealer at the CMU wall, another 2x6, was pre-installed against a retrofit insulated panel in Figure 12. The panel was installed above the window in Figure 11 where the 2x6 was allowed to run wild.

Inverted Ledger Plate

The existing rear foundation masonry had been installed with a sloped profile at the outside grade in an attempt at dispelling rainwater from the foundation. Because of this, the ledger that carries the first retrofit panel and provides its edge seal had to be installed inverted to accommodate the condition and maximize the wall coverage. Figure 13 outlines the standard detail for ledger attachment.

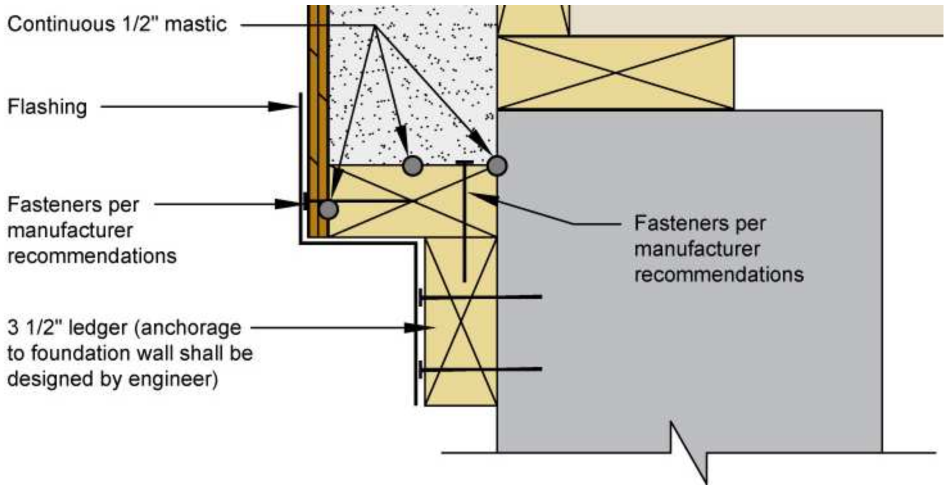

Figure 13. Typical Ledger Detail

The ledger also serves as an insect guard at the panel bottom after the foam is adhered to it and the OSB is fastened to its edge. Figure 14 shows that the ledger at the flared foundation was supported from a 2x4 above the ledger rather than below. This required an additional groove to be cut in the foam panel, doubling the cut labor at this location, Figure 15.

Figure 14. Inverted Ledger to Accommodate Sloped Foundation Wall Beneath

Figure 15. Panel Edge Grooves for Inverted Ledger

Aerogel fabric was installed behind the rear stair landings underneath the patio doors to provide some additional thermal resistance and an air seal because the stair assembly could not be removed for access. The 10 mm thick fabric provides a thermal resistance of R-4 and is vapor permeable, but wind resistant, Figure 17. The material was installed at the band boards behind the rim of the metal stair landing and sealed around the lag bolts supporting the stair assembly, Figure. 18.

Figure 16. Patio Door Band Board behind Stair Landing Completed

Figure 17. Aerogel Fabric

Figure 18. Aerogel Fabric between Stair Landing and Band Board below Door

Redundant Weather Resistant Barriers/Drainage Planes

The building's original WRB was left in place when the siding was removed. It was left in place chiefly to protect the structure during retrofit, as the vinyl siding was removed during the first two days of the three-and-one-half-month-long project. For future builds it would be advisable to remove the siding in smaller batches to leave the building protected while work is in progress.

The wall assembly consists of many layers, each of which would be expected to provide air sealing in their own right – OSB-sheathed 2x4 walls with insulation and drywall, WRB, 4-inch or 6-inch nailbase panel with OSB face, and another WRB, overlapped and taped. The lack of performance improvement that was seen following the blower door test after installation posed the question as to whether the leakage that was being measured was actually wall leakage.

SIPS Seal, a mastic, was used for panel to panel adhesion at planar irregularities. The sealant provides a permanent bond that retains flexibility. The formula bridges gaps up to 9 mm (about a third of an inch), thus, it is a very good sealant for nailbase panels bridging an existing, imperfect wall. Mastics are moisture and temperature fluctuation resistant, once cured, and provide good resistance to weathering. A two-part spray polyurethane foam was also supplied to the job, which was intended to be applied to the foam EPS surface between panels. This approach appeared to be used with less success than the mastic, in part due to the product's spray nozzle being undersized for a single shot delivery of the desired 3/8 in. bead.

Figure 19. Application of Panel-to-Panel Adhesive

Optimum panel to panel adhesion is shown as two continuous straight beads of sealant (approximately 3/8 in. thickness) for most applications shown in the Installation Guide. It seems that the location of the adhesive beads at the panel's edge may be more critical than what was stressed by the trainers, based on the initial results testing the building's air seal. The spray foam visible at the side of the panel staged on saw horses in Figure 19 (horizontal panel in foreground) shows what may have been a typical panel-to-panel application of SPF that does not appear to be continuous. How long this panel stayed on the saw horses prior to setting the panel in place is another unknown. For effectiveness, the SPF sealant must not be allowed to dry prior to installation of the panel; otherwise the sealant may act as a spacer between the panels, causing an unintended air leakage gap. Scrutiny of the graphic details in the Installation Guide indicates that a single 3/8-inch bead of adhesive is required in proximity to the OSB edges of each abutting panel in order to effect an air seal.

Methods That Didn't Stand Up in Hindsight

Two-part spray foam for panel to panel connections does not work well in winter. The supplier shipped the two-part SPF in a 24 pound box that was bulky to use and store. Tandem six foot long hose lines fed a single applicator nozzle but the long hose lines coiled and cooled the chemical content(s) and just didn't deliver adhesive to the panel edges well. The nozzle was inadequately sized to deliver a continuous stream along 8 foot and 10 foot lengths. Spray foam is best suited for voids in excess of 3/8 of an inch. A typical ideal condition for the two part SPF use ranges in temperature from 60°F - 90°F[11].

The mastic that was also on site provided a more effective delivery mechanism using sausage rolls in a manual applicator (caulk gun), however, the manufacturer's tested effective temperature range is similar to the range of SPF; 45°F - 90°F.[12]

A panel edge sealing methodology that can be more easily applied, and remains effective during application in the sub-freezing temperatures, is necessary for the widespread success of the retrofit panel product. Alternatively, attention to detailing the WRB as the air barrier, may provide the simpler solution to effective use of the insulating panels.

LESSONS LEARNED

Co-ordination of Mechanical Electrical and Plumbing Trades for Service Extensions

The building owner accepted the responsibility to hire the plumber to extend the polyvinyl chloride (PVC) pipes and the metal concentric piping that provide hot water equipment and heat exhausts, largely because the contractor would not include the trade work in his scope. Ideally, the pipes should have be extended prior to panel installation, however, the lack of schedule coordination between the contractor and the building owner resulted in the rear panels being installed with large openings cut to accommodate the PVC elbows that terminated in mid-panel, Figure 20. The PVC piping was cut, after which a straight extension was installed, and then a panel patch was installed, then the elbow was installed on the PVC pipe. Coordination at the beginning of the panel installation would result in a neater, tighter, more streamlined job.

The contractor accepted responsibility for any electrical extensions that were required because an electrician was kept on staff. Thus, the electrical work progressed in tandem with the installation of retrofit panels which is the preferred method with all of the specialty trades.

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[11] http://dow-styrofoam.custhelp.com/app/answers/detail/a_id/4596

[12] https://rcdmastics.com/images/stories/pdf/8pds.pdf

Figure 20. Large Rectangular Cutouts to Accommodate Water Heater Direct Vent Piping

Bowed Panels and Sub-Assemblies

The solution for a bowed retrofit insulated panel is to fasten the panel to the wall from the bottom up using double the number of screws required and tighten these incrementally moving across the panel width. The extra screws can be removed and re-used after installation and the holes filled with foam. The six-inch panels tended to bow in the middle of their length which is said to happen when OSB absorbs moisture. Panels were properly stored off the ground and covered before installation. OSB will take on moisture when exposed to high humidity conditions, thus the bowing may have resulted from atmospheric conditions. Daily average exterior relative humidity ranged from 53% to 100% during the month of December 2013[13], when the phenomena was observed.

The basement apartments in the building were abandoned in a 1998 rehabilitation of the buildings. Rear door and window opening were closed up with 2x4s, insulation, sheathing, and radiant barrier-like insulative foil scrim material. Upon close inspection, the exterior wall surface in this area contained bowed sheathing and was out of plumb as much as two inches in eight feet. Installers attempted to "float" the panel installation in this area to bridge irregularities that could not be repaired. The installation resulted in some retrofit panel edges that were 1/8 in. to 3/16 in. out of plane (referred to by the trade as "saw toothing"). The crew believed they could cover these irregularities with the vinyl cladding. A SIPA trainer that was on site at the time was concerned about the integrity of the air seal at these out-of-plane joints, and advised that all edges be sealed with mastic applied by trowel. (Figure 20, previous.)

The retrofit insulated panel's success as a system for delivering additional thermal resistance and air seal relies on panel-to-panel sealing and sealing at intersecting planes as the basis for the system's

[13] www.wunderground.com/history/airport/KALB/2013/12/1/CustomHistory.html?dayend=31&monthend=12&yearend=2013&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=

effectiveness as an air barrier. The installation at this project highlighted a number of pitfalls that contractors will need to address in the application of the retrofit panel technology.

Clearances at Egresses

Typically, an increase in wall thermal performance would be achieved using one consistent panel thickness to achieve the R-value target. In this case, a weighted average wall R-value approach was necessitated by two facts of this demonstration building – the desire to retain the aesthetic of the split-face CMU wall and not cover it with insulated panels and retaining egress at the front stairways and landings. Figure 21 shows the transition from a 4 in. to a 2 in. panel around the door at left. These reductions in retrofit panel thickness were required to maintain minimum clearances at the landings adjacent to the three doorways accessing each section of the building. This use highlights the flexibility of the method to accommodate the many architectural nuances in existing structures.

Figure 21. Retrofit Panel Step-Down in Thickness at Entry Landings

RESULTS

Table 4 summarizes the goals of the project. The project managed to achieve two of four goals for the demonstration – opaque wall R-value and cost per shell square foot. The following discussion will cover these targets in depth.

Table 4. Recap of Project Goals and Actual Achievements

Target	Project Goals	Actual Results
Opaque Wall R-value (weighted)	R-25	R-27
Air Seal, CFM50	3,968	9,435
Cost, SSF (affected area)	≤ $10.00	$8.87
Energy Savings (Heat & Hot Water)	30%	14%

Wall R-Value

The calculations covering the weighted average of the opaque wall R-value are contained in the separate file named *RIP - Appendix C*, the *Energy Simulation Analysis* that was provided at the outset of this project (the wall weighted average calculations have been amended to reflect the use of graphite-enhanced EPS and its superior thermal resistance). The strategy combined 6-inch, 4-inch, and 2-inch Neopor panels to maintain clearances and aesthetics while providing an overall average R-value to the building's above-grade walls in excess of R-27.

Air Seal

The blower door test zone consisted of the three or four units (including basements) in each vertical section of the building that were separated by the CMU block walls. The leakage test plan consisted of using three blower door units with operators to measure each of the three vertical sections' units solo and then simultaneously. The difference between the solo depressurized leakage number and that unit's leakage when all of the units were simultaneously depressurized to 50 pascals was interpolated to indicate the leakage to the adjacent units while the sum of the leakage numbers noted when all three units were depressurized to the same 50 pascals, was recorded as the combined leakage to the outside. Guarded blower door tests were not performed between units adjacent to the CMU walls, as the CMU walls were initially assumed to be airtight and additional blower door units and staff were not available. (Ideally seven blower door devices, and staff to operate, would be required for an accurate measurement of net leakage to the outdoors.) Because of this approach, leakage to the outside could be overstated, however, software simulations of the actual after retrofit condition do not support this. (See *Energy Savings* section.)

The four adjacent units in the middle tower were air leakage tested in a daisy-chained fashion to calculate the difference of the four adjacent units in the middle using only three fans. That is, the basement, first floor, and one second floor unit were tested solo and collectively. Then, the basement and both second floor units were tested, then the first floor and both second floor units were tested. Test results for all of the units are shown in Table 5.

Table 5. Building Air Leakage Test Results

Unit	Before Condition[A]		Final After Nailbase Panels/Attic Insulate/Seal			
	Measured	Net Leakage Out	Solo Leakage	Leakage to Adjacent	Net Leakage Out	ACH50 Per Unit
153Bsmt	2,491	1,391	2,550	1,100	1,450	10.5
153A	1,607	923	1,219	684	535	3.9
153B	1,773	1,073	1,500	700	800	5.8
152Bsmt	3,729	2,099	3,300	1,630	1,670	8.0
152A	2,680	880	2,200	1,800	400	1.9
152B	1,934	980	1,699	954	745	6.9
151A	2,228	913	1,700	1,315	385	3.6
150Bsmt	2,445	1,495	2,800	950	1,850	13.3
150A	1,851	798	1,690	1,053	637	4.6
150B	2,484	1,593	1,854	891	963	6.9
Total	**23,222**	**12,145**	**20,512**	**11,077**	**9,435**	
Air Seal Improvement					22.3%	
Building Leakage (ACH50)		8.3			6.4	

[A] Before condition assumes same unit-to-unit leakage as the final condition.

The final air seal results, the reduction of air leakage to the exterior by 22%, was poorer than had been planned, perhaps due to over confidence in the air leakage reduction that the wall retrofit, alone, would produce. In large part, the demonstration building's design, construction, and use contribute to this result due to:

- A wide range of architectural features, including split-face block walls that were not insulated with nailbase panels or sealed and numerous offset wall details.

- The 1998 attic retrofit of a gabled roof over a flat roof (where it is expected that numerous air leakage pathways were created).
- Aging windows that were difficult to close.
- Installation during weather that was consistently below freezing.
- Not identifying key wall and basement leakage pathways at project outset

These conditions all may have contributed to the project's not meeting infiltration reduction targets. This experience would indicate that the nailbase panel product, alone, particularly in the AHA building, does not provide sufficient air seal to meet stringent air leakage specifications.

The contribution to air leakage by stack effect became apparent during the final blower door tests where it was noted that basements articulate directly with second levels via a common stairwell and possible hidden chimney(s) containing pipes for the retrofitted fire sprinkler system. CMU walls were capped in the attic as per the scope of work for the attic air seal, however, there are likely other undetermined leakage pathways through the CMU wall. Visual inspection from the abandoned basement units indicated that the CMU blocks had been penetrated by receptacle boxes installed in the party wall of all units, as per Figure 22.

Figure 22. Abandoned Basement Receptacle at CMU Wall

Other leakage pathways have been created by maintenance personnel since the retrofit was completed. Door sweeps on all four basement doors and the door to the electrical closet were omitted to allow maximum air flow into the basement in an effort to minimize conditions for mold growth. Door gaps of 3/4 inches between the threshold and door bottom were noted at the four 36 in. openings. Between the start of the project and its conclusion two years later all six water heaters in the basement had been replaced with power vented, more efficient models and the 4 in. through-the-wall PVC pipes which had provided combustion air to the old units were abandoned with fiberglass insulation fill. (Maintenance records do not indicate when the water heaters were replaced, thus, these have only been used in the final, and not the interim, post-retrofit panel-installation, energy simulations.) Basements were responsible for the largest volume of air leakage reported in Table 5.

The occupant of one of the units requested the removal of the compression weather stripping that was installed at the front door because she found it hard to engage the lock on the door. Inspection indicated that the steel jamb had been forced far out of plumb and should have been repaired or replaced.

Both new and old windows are vinyl double hung units with compression fittings at head and sill that made fully closing the windows impossible without latching them. Seventy to eighty percent of the windows in the building were not fully closed when they were inspected and closed (in March) to perform the blower test. For ease of use and maintenance, only single hung windows should be specified in the future.

In summation, the retrofit insulated panels provided the thermal resistance required to meet that project goal, but the project did not meet the air infiltration reduction goal. The specific component(s) of the building that were responsible for the deficiency were not easily identifiable.

Energy Use

A calculation of the improvement in energy usage during the months of February and March in each of the past three years, normalized by utilities actually used divided by the heating degree days (HDD) in the period, is shown in Table 6. This period was selected because the data is available for all three years of interest and February falls just after the completion of key steps in the retrofit process – base (2013), post installation of retrofit panels (2014), and after air seal and attic insulation (2015). Based on the normalization ratio, the energy use is calculated for a typical 1,200 HDD period and the savings are calculated. Results are lower than the software simulation of the after-retrofit condition due in part to the high temperatures that are maintained within the units (Appendix F).

Table 6. Normalized Energy Savings for February & March (Post-Retrofit)

	March/ February HDD	Gas Use (Therms)	Ratio Therms /HDD	Electric Use (kWh)	Ratio kWh/ HDD	Use Normalized to 2,250 HDD		Energy Savings from 2013 Baseline		
						Therms	kWh	Therms	kWh	Btu
2013	1,995	1,740	0.87	1,828	0.92	1,963	2,062		Base	
2014	2,330	1,902	0.82	1,894	0.81	1,837	1,829	6%	11%	7%
2015	2,444	1,835	0.75	2,222	0.91	1,690	2,046	14%	1%	14%

The energy savings results, 14%, for the February and March of 2015 heating season, are about 50% lower than predicted by computer simulations. Confidence in predicting savings relating to the AHA building is compromised by the following factors:

- Reductions in air infiltration rates were less than anticipated (see the discussion preceding *Air Seal* section on leakage rates)

- Infiltration plays a significant role in energy use and further reduction in air leakage in these building types is recommended

- During the winter months interior temperatures fluctuate between 5 and 10 degrees F on a daily basis.
  - It is not known whether the occupants were responsible for this fluctuation or whether boiler controls were not operating properly, as it is unlikely from observation and questioning that occupants adjust the hydronic controls within their units with any regularity.
- Lack of simple controls within units,
  - Non-temperature based controls are provided at each slant fin radiator in the form of Macon gate valves with numerical dials, however, these are typically located low against the wall and hidden behind large pieces of furniture, discouraging active use.
  - The lack of any temperature measurement devices in the units did not provide the occupants an opportunity to associate the control of the heating system with a desired interior temperature.
- Difficult window operation
  - When performing blower door testing during the active heating season, most windows were found to be unlatched indicating that they were most likely not latched at the beginning of the heating season or remain in active use during the winter months. Furthermore, most windows were found to be very difficult to latch, discouraging securing the window to limit air leakage.

Improvements to the control of the heating system, including easy-to-use thermostats with clear temperature measurement, is recommended in tandem with the Phase II upgrades. In the interim, digital desktop temperature and RH gauges were provided to the occupants in Building 150 Lark. Window sash lock/compression weather strip repair is also suggested.

Notwithstanding these challenges to maximum energy efficiency, the energy savings which ensued from this project are project are significant and will accrue each year for the life of the building.

The simulated energy savings predicted ty BEOpt v2.3.02 was determined using interior average temperature set points of the measurements taken from the three stacked units (as three separate averages - 77°, 75°, and 75°).These simulated results advised decision-making as to the project (see Table 7).

Table 7. Software Predicted Energy Savings for Heat and Hot Water– Annual Basis

	Simulated Use (Natural Gas Therms)	Simulated Energy Savings (%)	Simulated Use (Electricity kWh)	Simulated Energy Savings (%)
2013 Before Condition	3,960		6,824	
2014 After Retrofit Panels	3,367	15.0%	6,678	2.0%
2015 After Panels & Attic Seal & Insulate	2,745	30.7%	6,576	3.6%
2018? Phase II Equipment Upgrade	2,307	41.7%	4,808	29.6%

At the outset, the building's simulated energy usage for heat and hot water was matched to within 15% of meter-recorded two year average usage (simulated usages were lower than actual). Predictive annual results however, do not compare to the one month's HDD-normalized actual usage shown in Table 6 despite inputting the measured building envelope leakage of 6.4 CFM50. As indicated in Table 7, the modeled energy savings after retrofit panels and attic seal/insulation was installed is about 31% versus the actual savings of 21% (natural gas which accounts for the primary energy usage in the building). These results indicate that the usage patterns of the units do not conform well to the models represented by the simulations. Two behaviors that have been noted that would confirm this are the high temperatures that are sustained within the units and the fact that air leakage via unlatched windows is probable. A few occupants mentioned that they open a window or rear door in the winter without turning off the heat. These factors complicate the alignment of the predictive data with the actual measurements in these buildings. In fact, the ten degree daily interior temperature swings that have been recorded coupled with the inaccessible location of the hydronic baseboard controls (behind bulky furniture) suggest that winter temperature control is via introduction of outside (cold) air after overheating occurs (Figure 23).

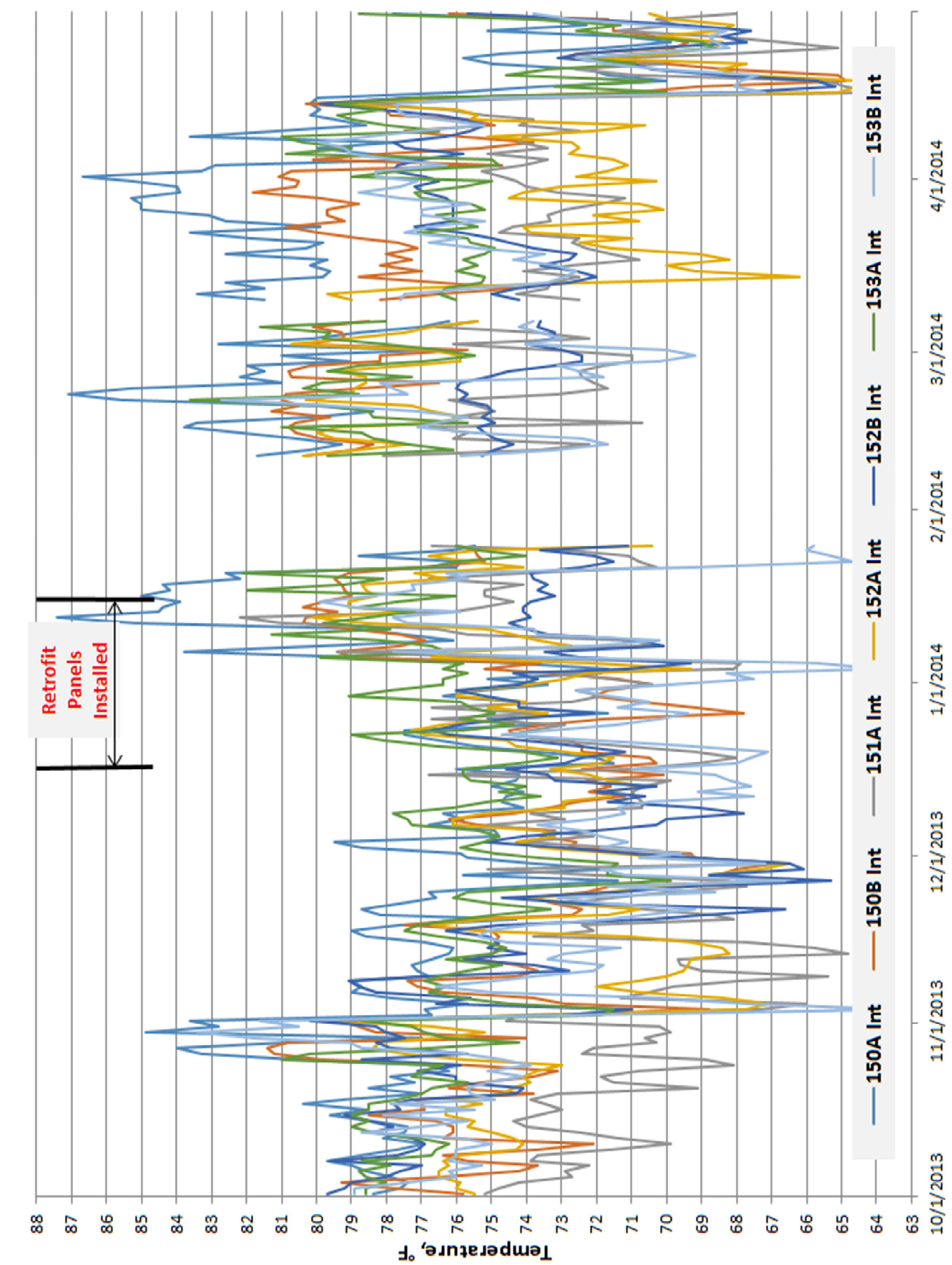


Figure 23. Indoor Temperature – Winter 2013/2014

Cost

Figure 24 indicates the actual cost of the exterior walls of this DER, based on the contractor's bid, broken into activities associated with the execution using RSMeans' *Building Construction Cost Data 2014*. The balance of the contractor's cost remaining after the activities of Demolition, Siding Installation, Siding Material, and Windows were tallied and allocated to the labor for the retrofit panels. The panels and accessories were donated by SIPA, thus, cost was known and accounted for accordingly. The sum of the siding and nailbase installation was $13.10 per SF of wall. The costs were broken down in this fashion to develop a ratio between the cost of the EE measures and the cost of the siding that would assist in the marketing of EE. For example it cost about 115% more than the siding to double the wall's R-value.

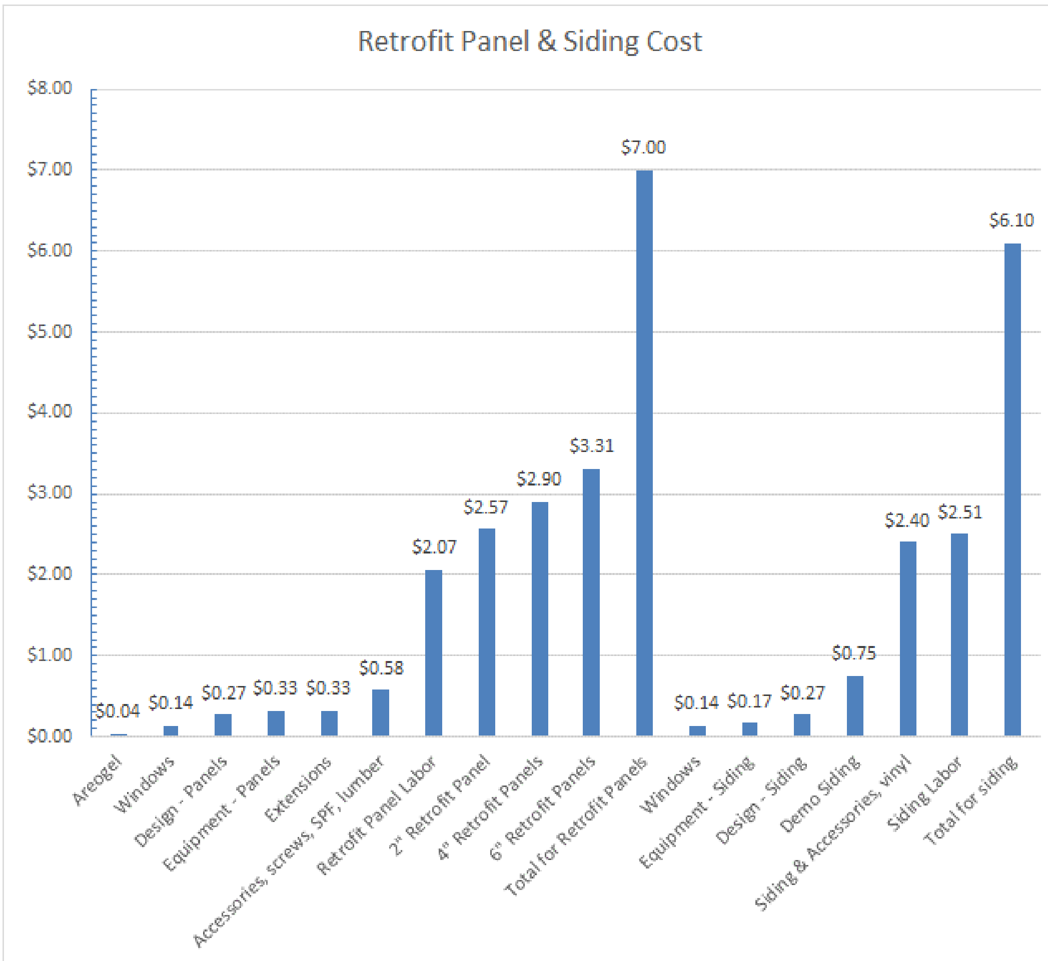


Figure 24. Cost to Retrofit the Walls

In addition to the panel and siding installation, air sealing in the attic, exterior door weather-stripping, additional insulation, and a ventilation strategy was planned. Albany Community Action Partnership (Albany CAP), which is responsible for a weatherization program funded team of retrofitters was recruited to finish up the weather sealing details because of their expertise in this area, as well as, an additional source of funding for the project. Costs associated with Albany CAP's effort are covered in Table 8.

Table 8. Cost of Attic Insulation and Air Seal and Ventilation Strategy

	Total Cost ($)
Attic Insulation, R-30	1,850
Air Seal Labor & Material	1,818
Ventilation Fans, Installed	4,000
Total Cost –Insulate & Air Seal Attic	**7,668**

In order to compute SSF of affected area, defined as the six surfaces that define the edge of the building's conditioned area which received retrofit tasks, Table 9 was drawn up.

Table 9. Calculated Shell Square Feet of Building 150 Lark Drive

Building Component	Square Feet
Attic	3,693
Walls Installed	7,060
Less Gable End Walls	(734)
CMU Walls	1,434
Total SSF	**11,453**

Project costs have been tallied in Table 10 and divided by the area of SSF that was calculated in Table 9. The result indicates that the project cost was $8.87 per SSF which met the demonstration project's cost goal of less than or equal to $10 per shell square foot.

Table 10. Calculated Shell Square Feet of Building 150 Lark Drive

Building Component/Activity	Cost ($)
Architectural Fees	3,900
Siding Demolition	5,391
6 in. Nailbase Panels	12,385
4 in. Nailbase Panels	9,699
2 in. Nailbase Panels	247
Fasteners & Sealants	3,037
Lumber	1,132
Nailbase Panel Labor	15,681
New Windows (4)	1,000
Aerogel Insulation	300
Equipment Rental	3,610
Extend Pipes, Wires	2,362
Siding & Accessories	17,223
Siding Labor	17,995
Attic Air Seal	1,818
Attic Insulation (R-30)	1,850
Ventilation Fans	4,000
Total	**101,630**
Cost Per SSF	8.87

The project is a monetary success at this step in the DER.

Building Moisture Levels

The Neopor EPS that was used in the panels is a Class II vapor retarder in the thicknesses which were applied to the building which slows the moisture diffusion through the retrofitted wall assembly. The exterior cladding and the success of the flashing and WRB installation will provide the building's defense against bulk water intrusion. With the addition of the retrofit panels, the dynamic moisture movement through, and accumulation in, the wall building materials, (i.e. framing, original OSB sheathing, new retrofit panel), will change from the original characteristics based on interior and exterior moisture levels.

The manufacturer stated accuracy for the sensors is +/- 2.0% RH and +/- 0.3°C which has been verified by PHI researchers.[14] Measurements of the wood moisture content (MC), by building sections of units between CMU walls, are reported by the graphs in Figures 25 – 27 which indicate average daily sheathing MC ranges generally between 6 and 11% with a few sensors reading slightly over 14% (Figure 26 covering the units in the middle of the building). The maximum MC recorded is well below the 20% minimum threshold that might indicate the start of wood fiber saturation,[15] and is considered normal. There is a small but notable change in the existing wall sheathing MC from before the retrofit panel installation to after. Prior to the retrofit, the MC readings generally ranged from approximately 9% to less than 15% whereas following the retrofit, the MC readings fell to a range between 6% to less than 10%. This result implies that no negative moisture effects are indicated with the addition of the retrofit panels and the added insulation.

[14] Home Innovation Research Labs, 2012. *High R Walls for Remodeling: Wall Cavity Moisture Monitoring*. p. 15. www.nrel.gov/docs/fy13osti/55205.pdf

[15] Carll, C. G. and Highley, T. L., Journal of Testing and Evaluation, JTEVA, Vol. 27, No. 2, pp. 150-158, March 1999. *Decay of Wood and Wood-Based Products Above Ground in Buildings.* www.fpl.fs.fed.us/documnts/pdf1999/carll99a.pdf

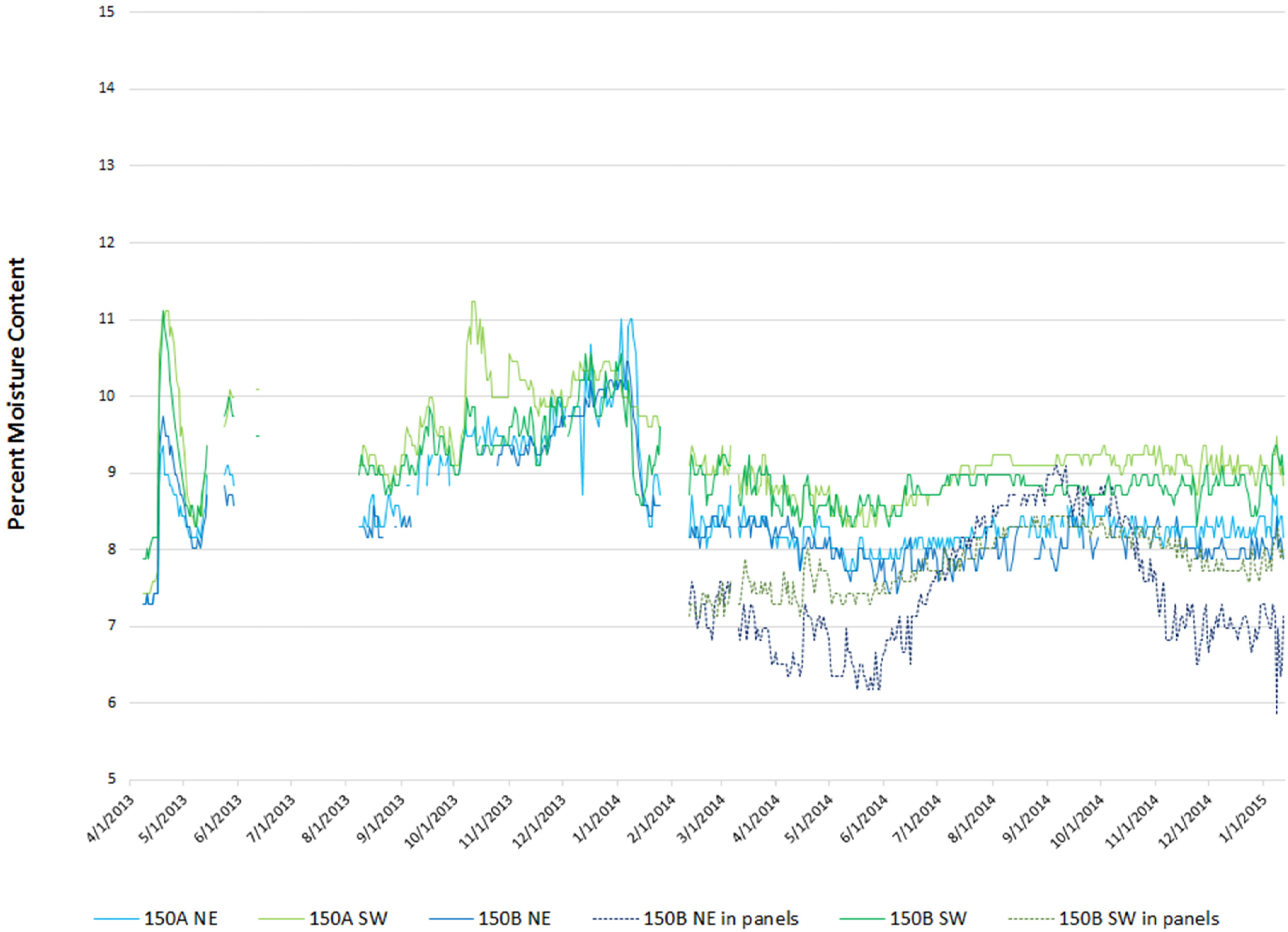


Figure 25. Moisture Content in Wall Cavities and Nailbase Panels – Units 15OA & 150B

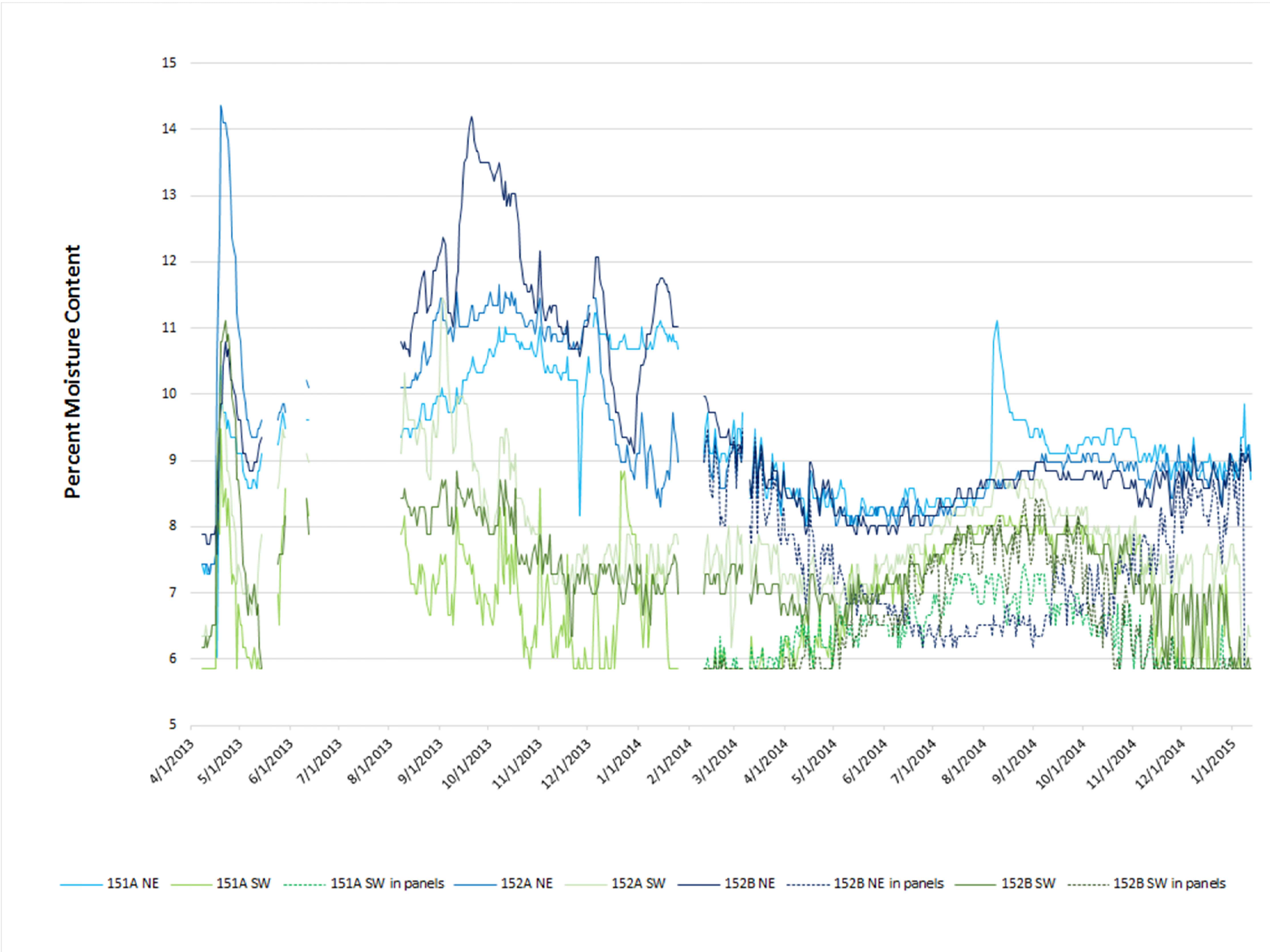


Figure 26. Moisture Content in Wall Cavities and Nailbase Panels – Units 152A, 152B & 151A

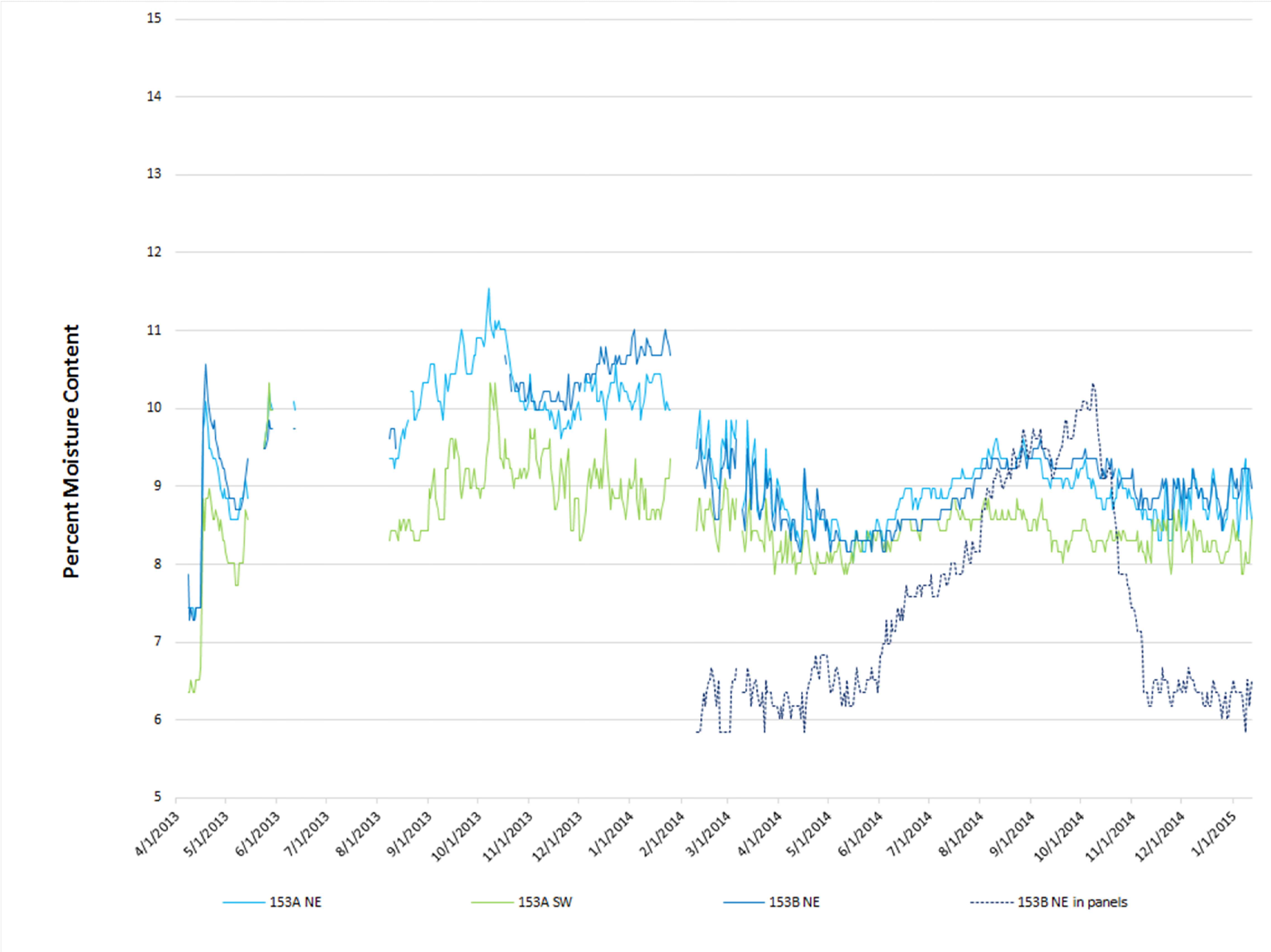


Figure 27. Moisture Content in Wall Cavities and Nailbase Panels – Units 153A & 153B

Moisture content will vary with ambient RH, the air tightness of the building and interior RH which makes RH another meaningful performance metric because as RH increases in a wall cavity the potential for condensation of water vapor on the outermost surface of OSB panels also increases. As relative humidity increases, the dew point temperature moves closer to the ambient temperature which makes RH a suitable metric for condensation potential. Comparison plots for the sensors located within the wall cavities and the temperature difference between the sheathing temperature and the dew point (DP) temperature are shown in Figures 28-30. Negative chart values (when the dew point temperature exceeds the sheathing temperature) would indicate a higher cavity DP than cavity air temperature near the OSB sheathing, with a resultant likelihood of condensation. This case was not noted in any of the wall panels or cavities.

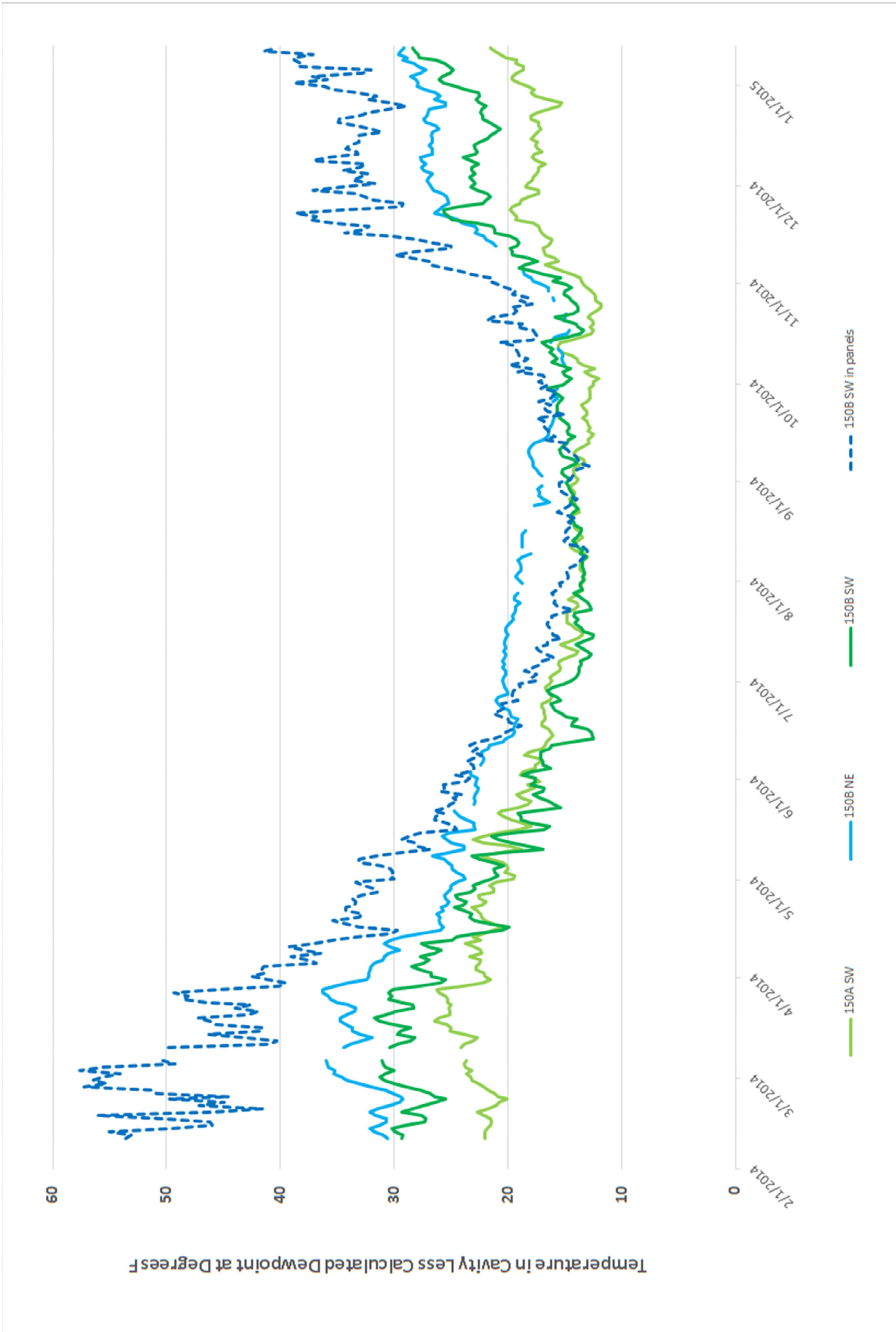


Figure 28. Condensation Potential – 150A & 150B

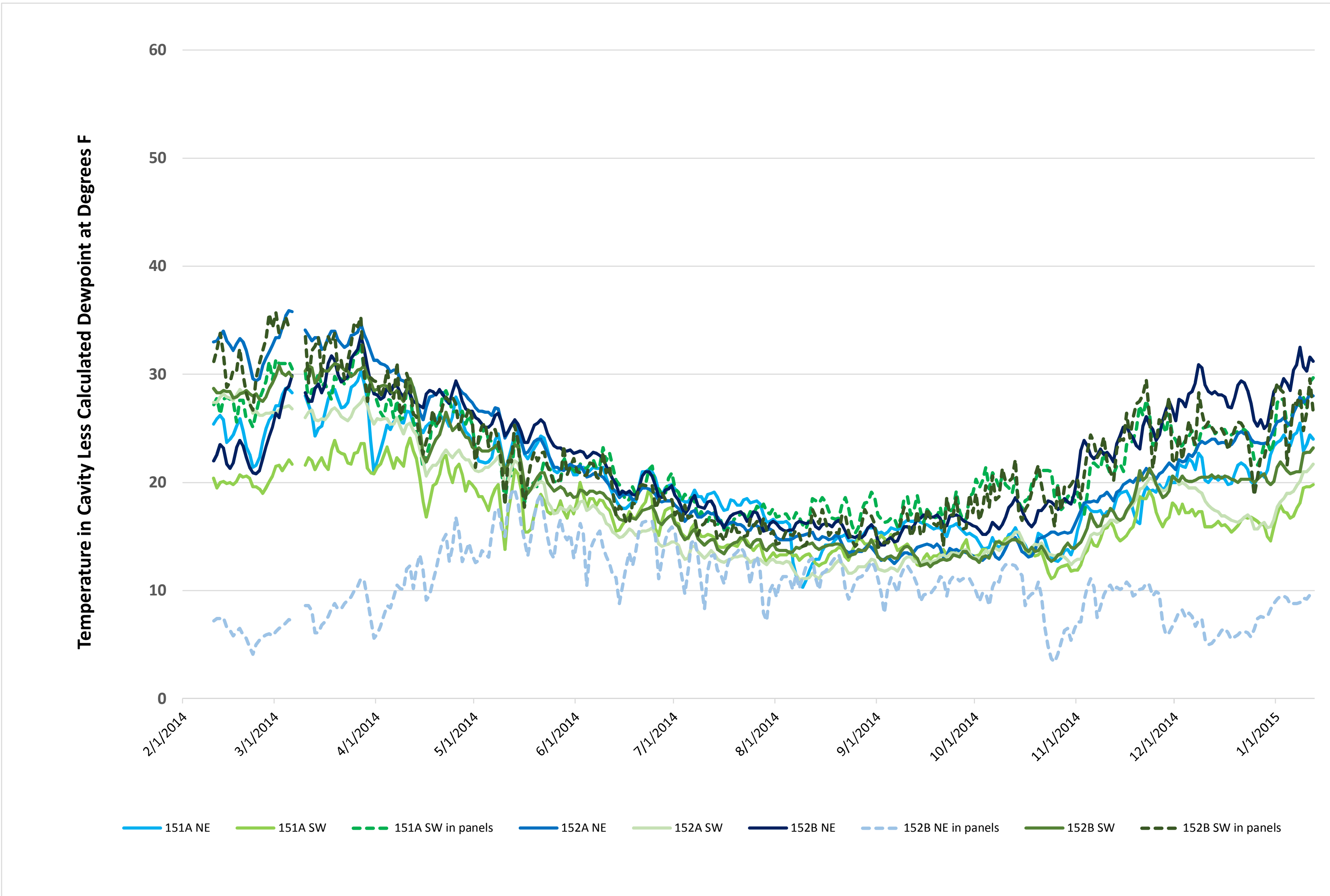


Figure 29. Condensation Potential – 152A, 152B & 151A

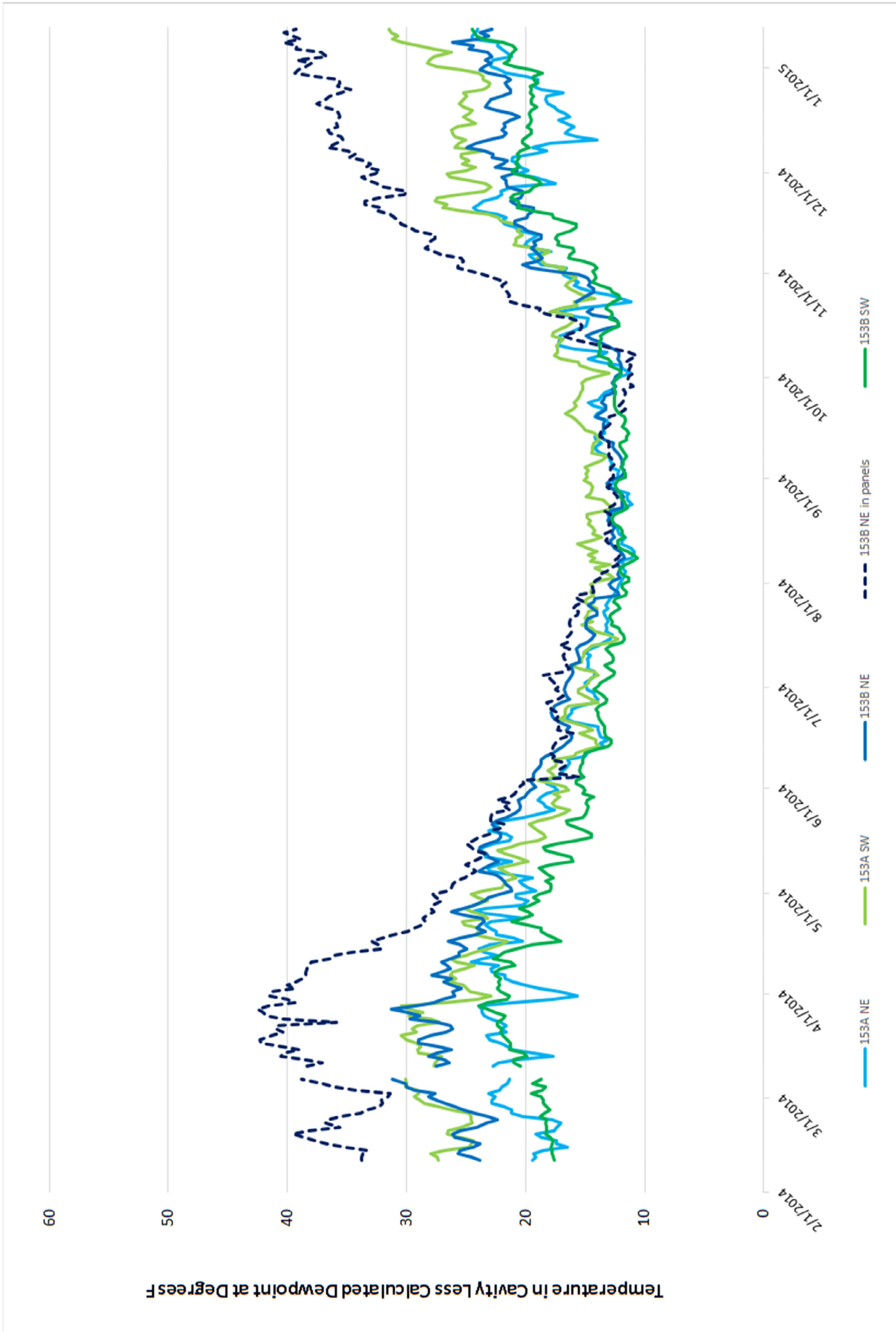


Figure 30. Condensation Potential – 153A & 153B

SUMMARY

Utilizing critical NYSERDA support, retrofit insulating panel technology was successfully employed in a multifamily building. The overall wall insulation for the building was doubled using a process that was demonstrated to be accessible to siding contractors with minimal training. The methodology to increase the wall insulation was primarily performed from the exterior and required minimal interior finish work. The retrofit panel technology confirmed the following benefits:

- Design details may be easily developed and communicated to contractors.
- Compiled actual costs indicate that the cost of adding an average of R-13 (doubling the wall insulation) is generally the same magnitude as new vinyl siding insulation.
- Installation allows for use of existing windows or new flanged windows.
- Use of an exterior weather resistive barrier can be easily employed using common standard installation methods.
- Synergistic opportunities such as air sealing around window openings, additional air sealing at eave and gable ends, and the addition of roof venting are easily employed with the use of retrofit panels.
- Complicated architectural details may be accommodated through use of different panel thicknesses and easily customized panels.
- Rapid development of contractor experience and added work scope value are expected incentives to continued use of the retrofit panels.

OUTREACH EFFORTS

1/2013, International Builder's Show, Las Vegas, NV
Tom Kenney, Vice President at Home Innovation, presented a case study to an audience of 35 in an education session at the International Builder's Show in Orlando FL on January 24, 2013. The study covered the proposed DER in Sag Harbor.

4/2014, SIPA Annual Conference, Ft. Lauderdale FL
Phil LaRocque, consultant to Home Innovation, presented a case study on Albany Housing Authority demonstration project at the SIPA annual meeting and conference on April 29, 2014, to an audience of 110.

3/2015, Residents of 150 Lark Drive, Albany NY
Two different questionnaires were submitted to the homeowners of the retrofitted building, one at the time of the April 2013 audit and another at the time of the March 2015 audit. Questionnaires which included a self-addressed stamped envelope were mailed to occupants approximately one week before the audits. When occupants were present during the audits, they were asked for the questionnaire or one was completed for them (with the occupant's input) at the time of the audit. The verbally delivered questionnaires are the only that were answered – there were three respondents to the 2013 questionnaire and two respondents in 2015 – of these two of the 2013 respondents also responded in 2015. Both of the respondents from the two years before and after the retrofit live in the units farthest from the boiler (heat generation) location, in units 153A and 153B. Both of these occupants noted that

their units were more comfortable after the siding had been installed (after January 2014). The occupants did not notice a difference after the attic air seal and insulation (after January 2015).

3/2015, Genesee Valley Academy[16], Batavia NY

Phil LaRocque, as a consultant to Home Innovation, presented a PowerPoint presentation on installation details and costs associated with the nailbase product used on the AHA project to two classes in a vocational technology middle and high school program in Batavia, NY on March 18, 2015. Approximately 40 students attended the morning class and 20 attended the afternoon session. Eighty-five percent of the student body and all of the Building Trades School faculty work in family-owned construction businesses.

Figure 31. A Class at Genesee Valley Academy Batavia, NY Campus

Market Penetration by Nailbase Panels

"As it has for the past nine years, the Structural Insulated Panel Association (SIPA) surveyed all known structural insulated panel manufacturers to determine 2012 industry production. A total of 101 entities are now on the SIPA master list. Many of these are past producers of SIPs, some have been determined to be foam producers only, while others have been determined to manufacture metal-skin panels that are now excluded from the tracked data. This list also includes nine plants that closed in 2010 or 2011, and seven more during 2012. Ultimately, 55 companies with a total of 65 plants were identified as having manufactured panels in 2012, including 18 SIPA members. All of these companies were contacted; hard data was provided by nearly 75%. There may still be a few more SIP manufacturers that have not yet been identified and attempts will continue to be made to include them in future surveys."[17]

The retrofit panel product is named "OSB One-Side" in the survey results. Table 11 shows the results of the 2013 survey and Table 12 shows the results for 2014 sales, indicating an increase of one half million square feet in retrofit insulated panel sales and better than a 3% increase in market share.

Table 11. Structural Insulated Panel Association's 2013 Sales Survey Results

Panel Types	SIPA Members (Millions SF)	Percent of Total
OSB Two-Sides	11.73	88
OSB One-Side	1.08	8
Plywood/Other*	0.45	4
Total	**13.26**	**100%**

[16] www.gvboces.org/instruction.cfm?subpage=208796

[17] *SIPA Survey of 2012 Production*, internal report shared for this report.

Table 12. Structural Insulated Panel Association's 2014 Sales Survey Results

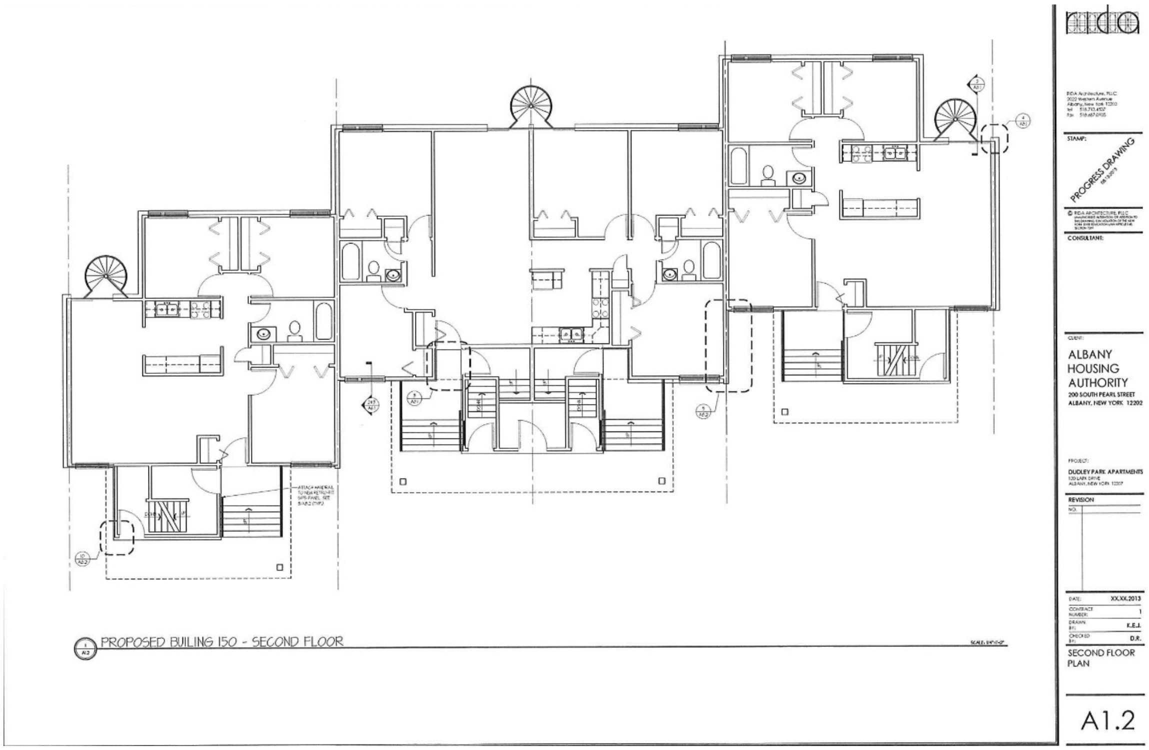
Panel Types	SIPA Members (Millions SF)	Percent of Total
OSB Two-Sides	11.70	85.2
OSB One-Side	1.60	11.2
Plywood/Other*	0.50	3.6
Total	**13.80**	**100%**

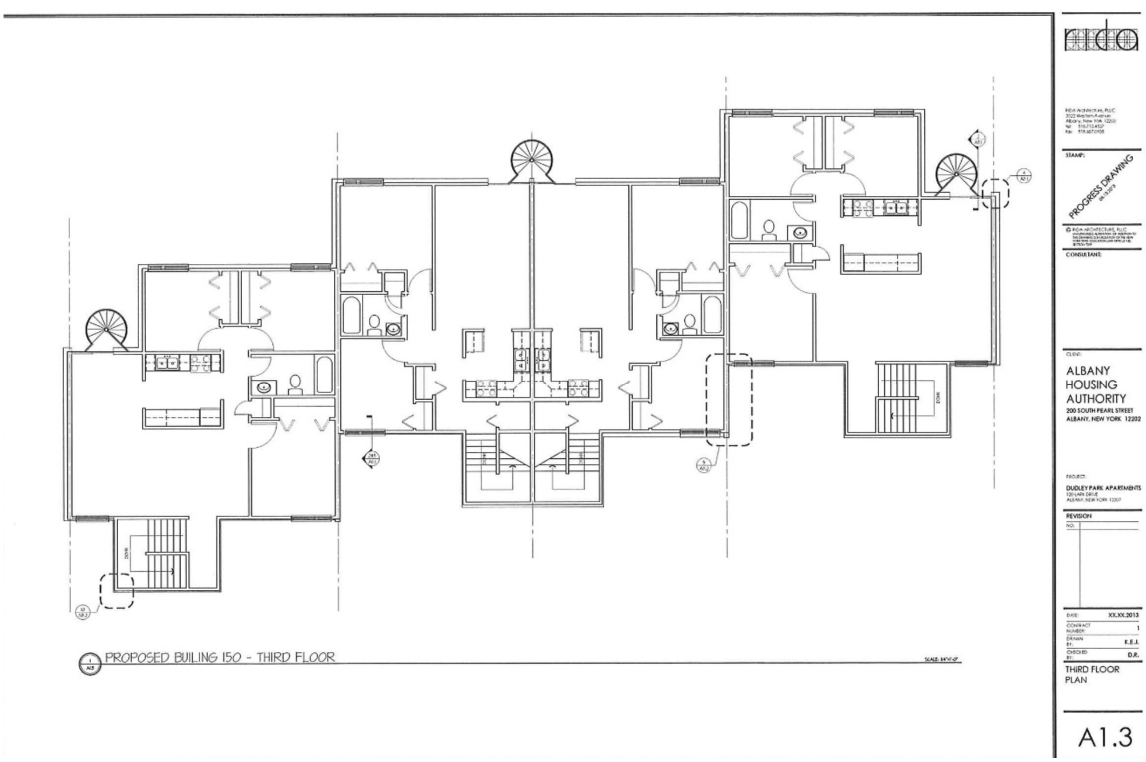
Table 13. Net Change in Market Share 2013 to 2014

Net Change 2013 to 2014 Panel Types	SIPA Members (million SF)	Percent of Total
OSB One-Side	.52	3.8%

SIPA's membership generally regard their SIPs and nailbase products as proprietary. After refinement of the Installation Guide, marketing efforts will be continued at the manufacturer level. This is expected to result in the Installation Guide being customized for/by each SIPA member manufacturer that chooses to promote the retrofit insulated panel product.

APPENDIX A:
PLANS





APPENDIX B:
ENGINEERED FASTENING SCHEDULE

schaefer-inc.com 1.800.542.3302

Project Name: AHA Retrofit SIPs

Project Number: 1312.54 Subject: Fastening Schedule

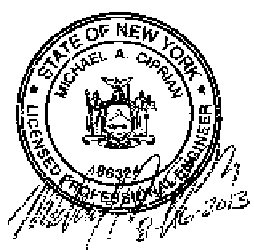
Date: 8/15/13 Author: TAM Page: SK1

schaefer

Retrofit SIP Panel Fastening Schedule

Panel Thickness	Screw Length	Screw Spacing
2"	4"	24"oc
4"	6"	24"oc
6"	8"	16"oc

1. Panel Joints should occur between supports
2. Screw spacing is into each stud/rafter/truss



IT IS A VIOLATION OF LAW FOR ANY PERSON, UNLESS THEY ARE ACTING UNDER THE DIRECTION OF A LICENSED PROFESSIONAL ENGINEER, TO ALTER AN ITEM IN ANY WAY. IF ALTERED, THE ENGINEER SHALL AFFIX TO THE ITEM HIS OR HER SEAL AND THE NOTATION "ALTERED BY" FOLLOWED BY SIGNATURE, DATE, AND DESCRIPTION OF ALTERATION.

Ref: NTA Engineering Evaluation Report TRU110910-21, dated 3/27/13

APPENDIX C:
ENERGY SIMULATION ANALYSIS WITH WA WALL CALCULATIONS REVISED FOR NEOPOR

(available under separate copy named "RIP Appendix C"

APPENDIX D: REFERENCES

BASF. *Building and Modernizing with Neopor®*, accessed 4/14/2014. http://www.plasticsportal.net/wa/plasticsEU~en_GB/function/conversions:/publish/common/upload/foams/Neopor_Building_and_modernising_with_Neopor_EN.pdf

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SIPA, et al., 2013. *Draft Retrofit Insulated Panel Installation Guide*. www.sips.org/downloads/DRAFT%20Nailbase%20Installation%20Guide%204-8-14.pdf

Wilson, Alex, 2010. *Avoiding the Global Warming Impact of Insulation*. www.greenbuildingadvisor.com/blogs/dept/energy-solutions/avoiding-global-warming-impact-insulation

APPENDIX E:
DISCOVERY PROCESS – OTHER PROJECTS CONSIDERED

The discovery process during which potential DER projects were identified consisted of contacting over two dozen local home builder association (HBA) contacts and responding to another large quantity of inquiries channeled through these and Nyserda.

The process of narrowing down the potential demonstration candidate sites required amassing and verifying quite a bit of information on each potential project location. This extensive preliminary groundwork included but was not limited to:

- An initial site and building owner assessment for suitability of the project to meet the requirements of the program,
- A review of the building construction, materials, access, roof, foundation, and windows to accommodate the retrofit products,
- Initial energy simulations to determine the extent of savings that could be expected, and
- Extensive planning to locate local contractors for the full site assessment, design, and construction of the retrofit project.

Some of the sites that served as runners up to the selected seven unit site at 150 Lark Drive, Albany NY, and for which extensive preliminary research was conducted, are itemized following.

St. Eustace – Lake Placid

This site was an approximately 4,000 sq. ft. 100-year-old church rectory. Most of the building's features were original. The structure was known to require new windows, new doors, new wiring throughout (knob & tube existing), insulation, and asbestos siding removal. Congregation members indicated that a $90,000 budget was in hand. Based on the initial positive response from the stakeholders, extensive research was performed to investigate the energy savings expected translated into payback estimates, testing of siding material to determine its composition, solicitation of local contractors to perform initial test-in analysis of the building and the energy retrofits and other upgrades. The congregation was expecting that Nyserda/partners would be able to match their $90,000 budget. The window package bid that the building committee had in hand for $52,000 was non-negotiable despite the availability of similarly-featured windows of equal performance for half of that price. The congregation's spokesperson, while passionate about DERs and building energy efficiency generally, had very definite opinions about brands, scope, and cost sharing that were unable to be met within the framework of this contract. Following an intensive three-month effort to negotiate a suitable compromise for the project and all partners, the decision to terminate was adjudicated.

Dewine Residence – Half Moon

The site was a ranch house with single car, attached garage, rear three-season porch, and in-ground basement. The first floor covered approximately 1,200 square feet. The features and vintage lent themselves to a retrofit with 4 in. panels, basement wall insulation, and attic air seal and insulation. Based on the intital favorable outlook for success, a preliminary energy and design analysis was performed including equipment upgrades. The homeowner intended to fuel switch from oil to propane and several budgets were drawn up, including Table 14. The homeowner would have financed the $16,024 cost via his utility bill and recognized annual savings of $74. Approximately $10,000 in air seal, basement insulation, and associated costs would be provided by the program sponsors.

Table 14. Proposed Project Budget – Half Moon

	Annual Savings	Cost	Monthly for 15 years	
			Pmt at 3% for 15	Savings
4 in. Nailbase Add R-14	378	8,821	(61)	32
.30/.48 windows	69	4,200	(29)	6
R-30 unfinished ceiling	287	1,289	(9)	24
R-49 main ceiling	155	1,714	(12)	13
Total	**889**	**16,024**	**(110)**	**74**

This owner, too, had large sustainability goals and worked as a consultant in an energy efficiency-related field. Following three months of negotiation, the project failed to move forward due to lack of financial commitment by the owner, as he too, was holding out for higher cost share with program sponsors.

Barrows Residence – Sag Harbor

This site presented an excellent demonstration project for utilizing the retrofit panels because of its balloon framing, accessible attic, and minimal existing insulation. The house is approximately 1,400 square feet with a partial crawlspace and partial basement foundation. Extensive investigation into the design of energy upgrades, including simulation runs to assess cost savings was performed. The energy upgrade that was planned included using retrofit panels to insulate the roof and utilize the attic space as storage and room ceiling expansion at the second level. The existing siding required asbestos remediation. Homeowner's application for on-bill financing for half of the retrofit cost was rejected due to business setbacks that affected his credit rating encountered by the economic downturn. No other financing source surfaced for the $35,000 to $50,000 retrofit. The budget is shown in Table 15.

In this case, the builder and homeowner was an enthusiastic and optimistic candidate for the demonstration project; he just lacked the resources or access to financing that would have allowed the project to move forward. During the nearly two years that the project was under consideration, he was unable to produce the funds to move forward even through his business operation's cash flow, which he had expected to flourish.

Table 15. Proposed Project Budget – Sag Harbor

Summary Report of Estimated Costs Associated with 169 Jermain DER													
Total Project Cost Estimates					On-Bill Financing			Owner Out-of-Pocket					
Option		4" Nailbase	6" Nailbase	Estimated Cost/Shell Sq. Ft.	On-bill Amount Financed for 15 yrs.	Total Monthly Payment @ 3%/yr.	Total Monthly Energy Savings	Additional Costs	Contract Participation Incentive	Net Upfront Cost of DER	Monthly Contribution to Energy Efficiency (EE)	Payback (Yrs) (Initial investment/ annual EE	Net Annual Cost after Payback of 70% at Resale[B]
Wall	Nailbase	4,797	5,640										
	Labor	2,472	3,708										
	Cellulose	3,642	0										
	Misc. Lumber	165	185										
Subtotal - Wall		11,076				(76)							
Subtotal - Wall[A]			9,534	2.30	9,534	(66)	87						
Foundation Wall	2" rigid foam to 2' crawl & 4' bsmt.		491										
	Install		378										
	ignition barrier & install		400										
Subtotal Foundation			1,269	0.31	1,269	(9)	13						
Crawl/Bsmt. Floor	Estimate Vapor Barrier Mat'l & Install		1,592										
Subtotal Vapor Barrier			1,592	0.38				1,592		1,592	0		
Roof	Nailbase		3,999										
	Labor		2,629										
	Misc. Lumber		186										
Subtotal 6" Nailbase Roof			6,814	1.65	6,814	(47)	5						
Wdws. .30/.30 Skylights	Estimate - JB $5K								Note that owner has opted not to replace windows. The $2,000 allowance covers labor/material to "box out" to assure access for replacement at a later time.				
Labor	Est. - $100 ea.		2,000					2,000					
Subtotal Windows/ Skylights			2,000	1.65				2,000	(7,000)	(5,000)	8	20	
Rheem 180K, 8.4 GPM tankless	Estimate- Home Depot		1,132										
Installation	Estimate		2,000										
Subtotal Propane Tankless Heat			3,132	n/a	3,132	(22)	31						
Subtotal DER Cost[C]			24,340	6.29	20,748	(143)	136	3,592	(7,000)	(3,408)	8	20	
Siding	Removal By Owner		0										
Fiber cement shingle, primed	Home Depot		5,340	1.29									
Install Labor	Estimate RSM		1,694	0.41									
Paint Labor	Estimate RSM		1,356	0.33									
SubTotal Cladding			8,390	2.03				8,390		8,390	0		
Roof Tearoff	Estimate RSM		636	0.15									
Roof Shingle	Estimate RSM		3,478	0.84									
Soffit, Fascia, Gutters	Estimate RSM		1,311	0.32									
Subtotal Removal & Re-Roofing			5,426	1.31				5,426		5,426	0		
Total Project Estimate			38,156	9.63	20,748	(143)	136	17,408	(7,000)	10,408	8	20	212

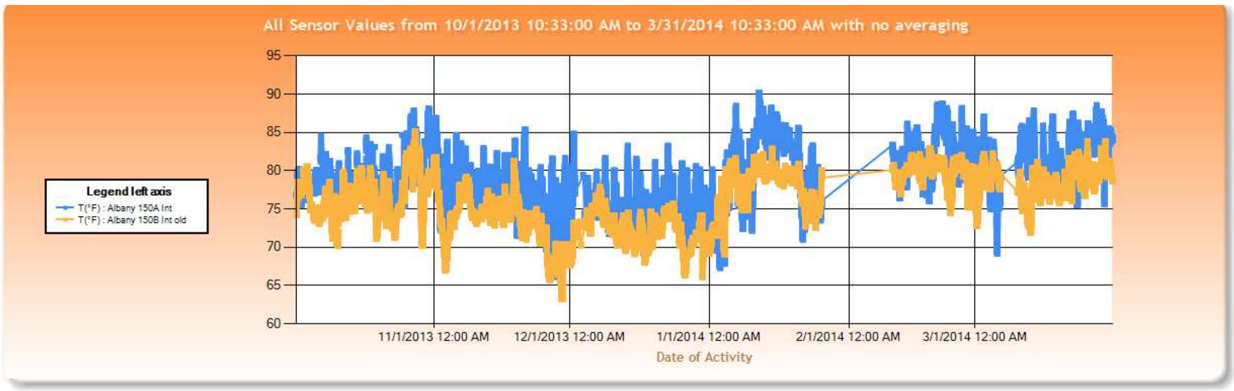
[A]Note: 4" wall & blown cellulose changes on bill financing by an increased $10/mo. payment.

[B]http://www.remodeling.hw.net/2011/costvsvalue/division/middle-atlantic/city/new-york--ny.aspx. Siding, 30 yrs. 67.1%, Roofing 20 yrs. 53.9% return, net of project incentive

[C]DER payback for on bill financed ECMs = 12 years.

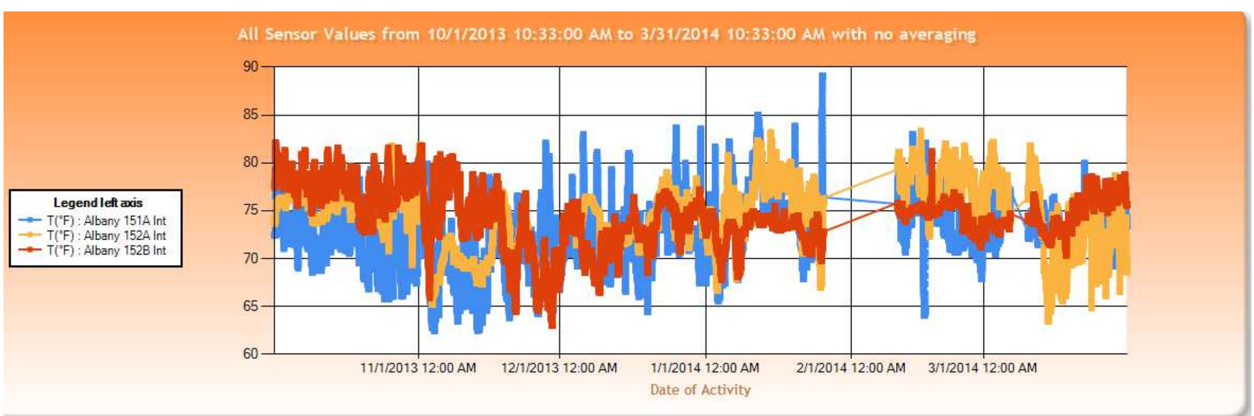
The demonstration site recruitment process took up to eighteen months and significant contract resources, as two of the three houses have had energy audits and energy simulation reports prepared. Preliminary budgets were drawn up for all of the houses which were considered. The sagacity was participants expected the project partners to cover much of the cost of the retrofit because Nyserda, in its role as research and development facilitator, had been rumored to have acted in that capacity under previous similar grants.

APPENDIX F:
INDOOR TEMPERATURES WINTER 2013-14 – HOURLY AVERAGE



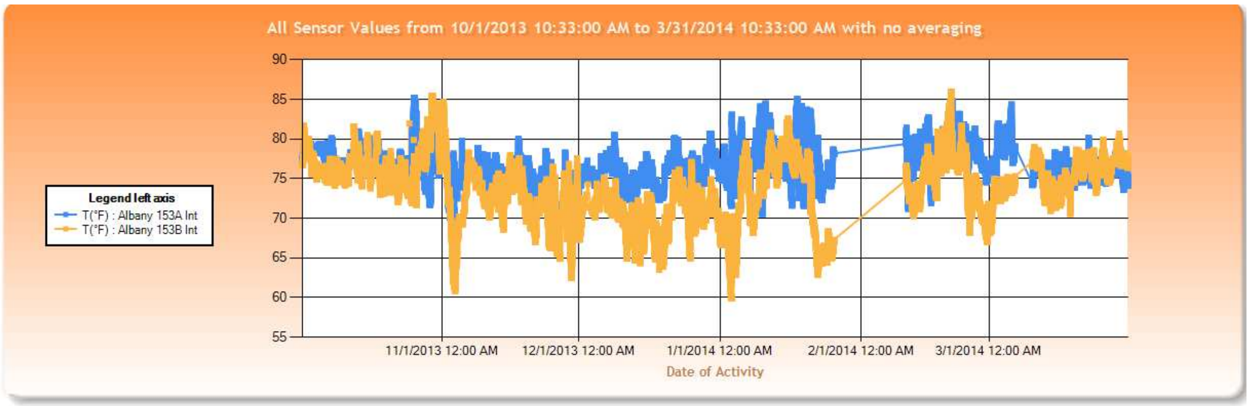
	T(°F) : Albany 150A Int	T(°F) : Albany 150B Int old
min	66.10	63.20
max	90.20	85.20
diff	24.10	22.00

Indoor Temperature 150A (Blue) and 150B (Yellow)



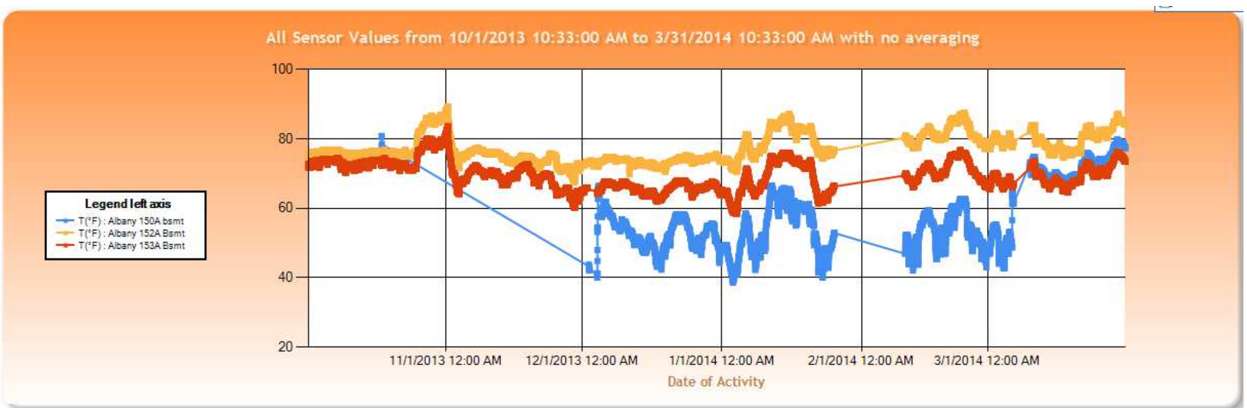
	T(°F) : Albany 151A Int	T(°F) : Albany 152A Int	T(°F) : Albany 152B Int
min	62.40	63.40	63.00
max	89.10	83.30	82.10
diff	26.70	19.90	19.10

Indoor Temperature 152A (Yellow), 151A (Blue) and 152B (Red)



	T(°F) : Albany 153A Int	T(°F) : Albany 153B Int
min	65.80	59.90
max	85.20	86.00
diff	19.40	26.10

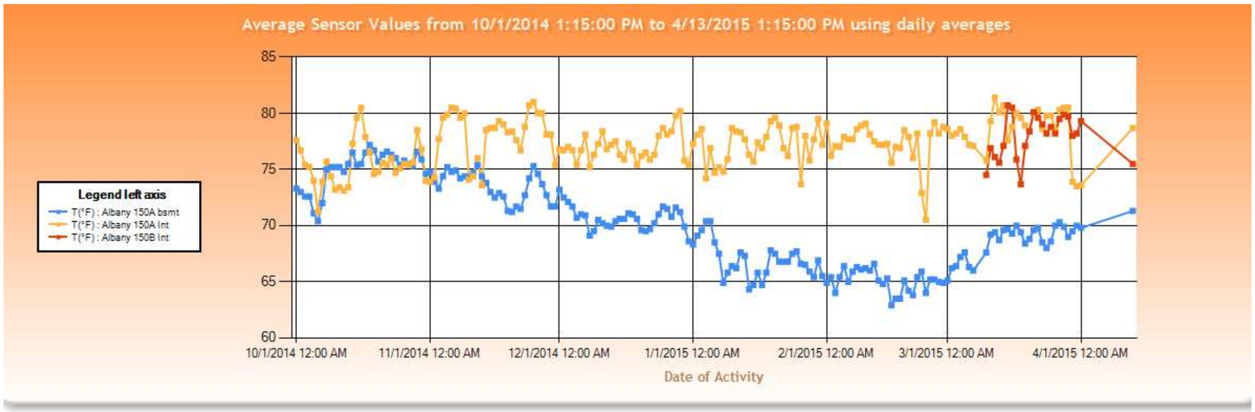
Indoor Temperature 153A (Blue) and 153B (Yellow)



	T(°F) : Albany 150A bsmt	T(°F) : Albany 152A Bsmt	T(°F) : Albany 153A Bsmt
min	38.50	67.70	58.40
max	80.90	89.20	83.60
diff	42.40	21.50	25.20

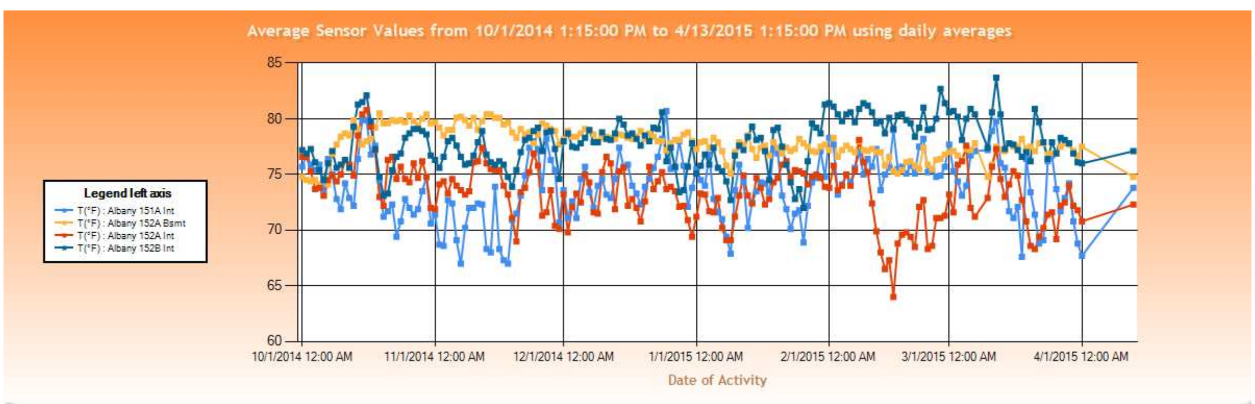
Indoor Temperature 150A Basement (Blue), 152A Basement (Yellow), 153A Basement (Red)

APPENDIX G:
INDOOR TEMPERATURES WINTER 2014-15 – DAILY AVERAGE



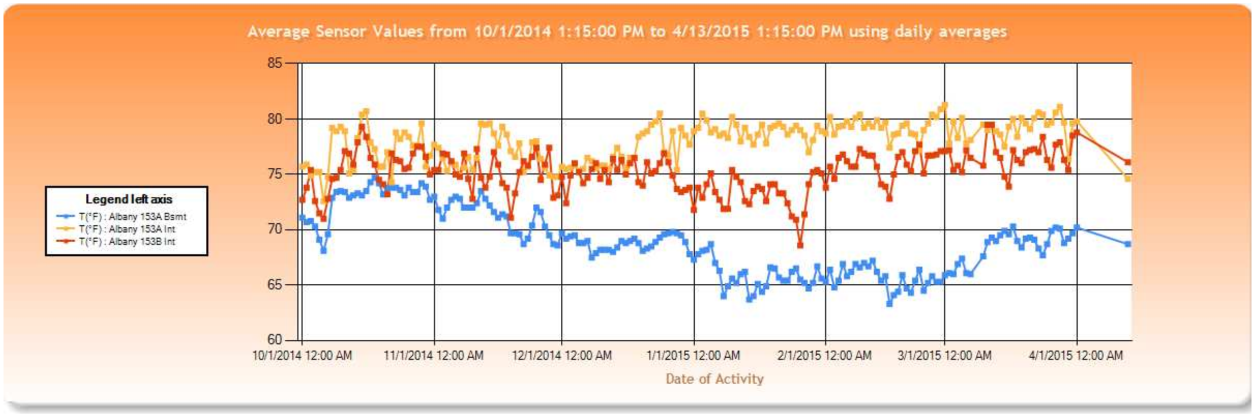
	T(°F) : Albany 150A bsmt	T(°F) : Albany 150A Int	T(°F) : Albany 150B Int
min	62.90	70.50	73.70
max	77.20	81.40	80.70
diff	14.30	10.90	7.00

Figure 32. Average Daily Temperatures – 150A Bsmt. (Blue), 150A (Yellow), & 150B (Red)



	T(°F) : Albany 151A Int	T(°F) : Albany 152A Bsmt	T(°F) : Albany 152A Int	T(°F) : Albany 152B Int
min	67.00	73.10	64.00	72.00
max	80.70	80.50	80.80	83.70
diff	13.70	7.40	16.80	11.70

Figure 33. Average Daily Temperatures – 152A Bsmt. (Yellow), 152A (Red), 152B (Dark Blue), & 151A (Light Blue)



	T(°F) : Albany 153A Bsmt	T(°F) : Albany 153A Int	T(°F) : Albany 153B Int
min	63.30	72.60	68.60
max	74.70	81.30	79.50
diff	11.40	8.70	10.90

Figure 34. Average Daily Temperatures 153A Bsmt. (Light Blue), 153A (Yellow) and 153B (Red)

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