Evaluating Exterior Insulation and Finish Systems for Deep Energy Retrofits

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Evaluating Exterior Insulation and Finish Systems for Deep Energy Retrofits

Final Report

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Abstract

Exterior insulation and finish systems (EIFSs) are proprietary synthetic formulations that are applied to the exterior walls of buildings to serve as insulation and exterior cladding. The insulation thickness can vary from less than one inch to as much as 16 inches. In this project, the applicability of EIFS for residential deep energy retrofits was investigated through the use of single-family and low-rise multifamily demonstration projects. The buildings were retrofitted using one of two styles of EIFSs: site-applied or off-site panelization. Each site employed a 4-inch thick EIFS, with an R-Value of 16. Site-specific details were developed as required for each retrofit application. Site work and the costs of the EIFS were documented. The demonstration homes were modeled using one of two simulation software programs: Building Energy Optimization or REM/Rate. This report discusses the cost effectiveness of the retrofit, the resultant improvements in energy efficiency, and the relative benefits of site-applied and panelized EIFS approaches.

Keywords

Deep energy retrofit, EIFS, exterior insulation and finish system, energy modeling, energy efficiency, air tightness, blower door test, panelization, wall panels

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Acronyms and Abbreviations

AERC	Annualized Energy-Related Costs
BEopt	Building Energy Optimization
DER	Deep energy retrofit
EIFS	Exterior insulation and finish system
EPS	Expanded polystyrene
HVAC	Heating, ventilation and air-conditioning
NYSERDA	New York State Energy Research and Development Authority
PTHP	Packaged terminal heat pump
WRB	Water resistive barrier
XPS	Extruded polystyrene

Executive Summary

Two case studies of deep energy retrofits using an Exterior Insulation and Finish System (EIFS) were conducted to evaluate this retrofit approach and to compare two variations: field-applied EIFS and an off-site panelized EIFS.

In the first demonstration project, a two-story, single-family home in Central Islip, NY was retrofitted using a site-applied 4-inch thick EIFS. The costs for the EIFS were about $15.50/ft^2 of net wall area (excluding windows and door openings), including the water resistive barrier and a standard finish coat. Costs for other insulation thicknesses mainly vary with material costs, as labor costs do not change significantly. Extrapolated costs for 2-inch and 6-inch thicknesses are $15 and $16, respectively.

The home was modeled using Version 2 of the National Renewable Energy Laboratory-developed Building Energy Optimization (BEopt™) energy and cost analysis software. BEopt modeling indicated that 4-inch thickness results in lower annualized energy-related costs compared to 2-inch and 6-inch thicknesses for a sample retrofit in Climate Zones 4 and 5. The 4-inch system can be cost effective (i.e., have a lower annualized energy cost compared to no retrofit) when the existing siding is at the end of its lifetime and the alternative is a high-end vinyl siding or similar cost replacement. The literature contains case studies of other R-15 to R-20 exterior-applied wall insulation retrofits at costs of $13–$25/ft^2.

While a package utilizing the 4-inch EIFS is the optimal retrofit of the options analyzed in terms of annualized energy-related costs; it is higher cost than replacing the siding with midrange vinyl alone. However, compared to high-end vinyl, the EIFS package has a lower annualized energy cost

The project achieved a blower door test result of 2 ACH50. While this is an indication of how tight an EIFS home can be, superior construction of the other components, such as the foundation, ceiling, and windows, which were impacted by the retrofit, contributed to the low air leakage test result.

For the second demonstration project, a 12-unit, low-rise apartment building was retrofit with a 4-inch thick panelized EIFS. Four of the 12 units at the demonstration site were modeled using Version 14.6 of NORESCO's REM/Rate energy modeling software. Pre- and post-retrofit models were generated to project the effect of the installed EIFS on thermal loads, with the specific objective of understanding the impact of exterior insulation retrofits on both the run times and cycling times for space conditioning equipment, as well as the air tightness of the enclosure.

Costs for the Saugerties case study were about $27 per ft^2 of net wall area (excluding windows and door openings) for the 4-inch thick EIFS, including the water resistive barrier, adhesive, caulking, and foam backer rods. Costs were $35 per ft^2 of net wall area when including preparation costs such as removing existing siding, adding roof overhangs, and demolishing the chimney. The higher net costs reflected a lack of labor savings relative to the site-applied case study at Central Islip.

Blower door testing at the Saugerties building was challenging because all apartments were exterior entry and so there was no common entrance on which to mount the blower door. Individual units were tested using guarded and unguarded testing, but large inter-unit leakage confounded results. Based on the average unguarded testing, it appears that overall leakage was reduced by 11% due to the EIFS retrofit.

This report discusses the risks, selection criteria, interactions with other building systems, cost, performance, and other aspects of using EIFS in deep energy retrofits. EIFS do not require special site safety precautions beyond general construction site precautions. Generally, fire codes permit EIFS for most building types and conditions as long as the EIFS has undergone the appropriate testing and approvals. Other safety precautions include moisture design, which is important in all wall systems, including EIFS cladding applications. If an interior vapor barrier exists and if there is not adequate ventilation through the drainage plane behind the insulation layer, trapping moisture between two vapor/air barriers is a risk. Face-sealed approaches that rely on exposed sealants do not provide acceptable rain control or durability and are also risky.

1 Introduction

1.1 Overview of Deep Energy Retrofits

The expression deep energy retrofit (DER) lacks precision, but broadly suggests a program of existing building improvement that has as its goal a dramatic improvement in energy efficiency while providing a healthier living environment and improving durability and safety. Adding insulation to exterior walls is often a key piece of DER. However, this measure is often cost prohibitive and there are formidable challenges to altering the thermal envelope of existing, older structures. This report provides two case studies of DERs that employ exterior insulation and finish systems.

Exterior Insulation and Finish Systems (EIFSs) are common in new and retrofit commercial construction. Such products typically consist of five layers installed over the top of a water resistive barrier as follows:

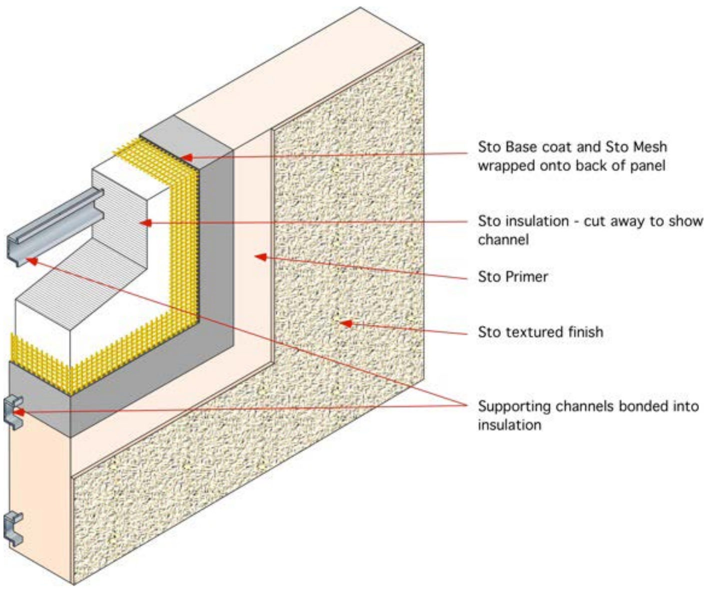
- Adhesive
- Foam insulation
- Base coat
- Reinforcing mesh embedded in the base coat
- Top or finish coat

EIFS can be applied to new or existing buildings that employ wood or masonry construction and can utilize an insulation thickness of up to 16 inches. However, such systems are rarely used in low-rise residential retrofits. Reasons for this might include a lack of demand for or knowledge of the systems in the residential retrofit industry, high cost relative to alternative solutions, or lack of suitable distribution channels serving the residential market. Another barrier that may limit EIFS retrofits is the change in appearance that would result from converting a vinyl, clapboard or brick home to an EIFS home. The stucco appearance of EIFS is accepted in certain regions of the country such as the West and Deep South; however, in colder regions where energy retrofits can result in greater energy savings, EIFS is an uncommon look for homes.

Off-site panelized EIFSs are further limited in present application, with no known examples of their use in low-rise residential retrofits. An example of an off-site panelized system is pictured in Figure 1. It includes rigid insulation with narrow metal channels embedded in the back for fastening, and a prefinished EIFS surface. Other materials required for this system include a water resistive barrier (often liquid applied) over the building sheathing and sealant between panels.

The insulation material most commonly used is expanded polystyrene (EPS), which has a low cost per R-value compared to other rigid board insulations. Unlike extruded polystyrene (XPS) which has an approximately 25% higher R-value per thickness, EPS contains little greenhouse gas agents (Wilson, June 2010); however, other compatible rigid board insulation materials could be used in place of EPS with little change to panel production or installation procedures.

Figure 1. Typical lightweight EIFS wall panel (courtesy of Sto Corporation)



While the final appearance of an EIFS installation resembles stucco, it is a distinctly different system. Stucco is a generic cementitious-based material, whereas EIFSs are proprietary synthetic formulations distributed by manufacturers to a network of authorized applicators. An EIFS is composed of polymeric (organic) bonded aggregate and cement reinforced with a glass mesh. Stucco is made of inorganic cement, sand, and lime.

1.2 Employing DERs to Achieve Energy Efficiency and Sustainability Goals

Interest in sustainability and carbon emission reductions are driving an interest in higher levels of energy efficiency for new and existing buildings. Performance of the building envelope is clearly critical in this endeavor. Whole-wall R-values of about R-30 (Aldrich, Arena, & Zoller, 2010) to R-40 (Building Science Corporation, 2010) (Wilson, 2009) are sometimes cited as targets for cold climate new construction or retrofit. High R-value building envelopes reduce energy consumption for space heating and cooling, in addition to enhancing thermal comfort for the occupants. Exterior insulating sheathings can significantly improve thermal continuity to achieve high R-value walls (Straube & Smegal, 2009). Deep energy retrofits of the thermal enclosure also can permit downsizing or elimination of space conditioning equipment because of lower loads imposed on the home.

To achieve a true R-30 wall, retrofits that add at least R-15 to exterior walls are generally required, as most existing homes do not have greater than R-15 walls. Higher values would be needed if existing walls have a lower true R-value or if higher final efficiency levels are desired, for example in colder climates. Achieving R-15 additional insulation requires an insulation thickness of 2–5 inches, depending on the material. With exterior insulation of this thickness, the issue of trimming around doors and windows and other details becomes a barrier, potentially increasing costs and complicating the work. As a result, exterior wall insulation upgrades at the levels required for a deep energy retrofit are often costly. In addition, they can be time consuming and disruptive to building occupants.

This project evaluates, via case study projects and modeling, one approach for exterior wall insulation retrofits that holds promise for lowering retrofit costs for certain building types: EIFS.

EIFS is suitable for a variety of existing substrates, including wood and masonry. EIFS is most commonly used in commercial construction but can be adapted for residential retrofit. Building types for which this alternative may be considered include low-rise residential buildings with vinyl or other siding that may need replacement and the unornamented sides and rears of many masonry structures. For larger, repetitive projects, the product can be fabricated offsite into prefinished panels and adhered to the building substrate with adhesives, potentially further speeding the work and reducing occupant disruption.

Costs are a major barrier to mass adoption of any deep energy retrofit solution. Building Science Corporation has performed baseline engineering and cost analysis on installing thick layers of exterior rigid foam insulation to wood frame and masonry walls (Peter Baker, 2012). The report found that insulation up to 1.5 inches thick was cost optimized because above that thickness, additional costs for cladding attachment were incurred. Depending on climate zone, insulation thicknesses of 4–8 inches were found to be cost-neutral compared to replacing cladding only (without insulation).

In a January 2013 report (Jan Kosny, 2013), Fraunhofer CSE estimated costs for various exterior wall insulation systems, including vinyl siding over 3-inch thick XPS (R-15) at $\$13.48/ft^2$ and vinyl siding over 5-inch thick EPS (R-20) at $\$13.92/ft^2$.

Building Science Corporation reported costs of $14.43/ft^2$ of wall to retrofit a two-story masonry home with exterior insulation and cladding with projected future costs of $12.60/ft^2$; and $25.31/ft^2$ to retrofit a three-story brick home using a similar system, with estimated future costs of $20–$21/ft^2$ (Neuhauser, 2013). These sources indicate that the cost of exterior wall insulation is in the $14/ft^2$ range for typical single-family homes.

1.3 Project Objective

The objective of these demonstration projects was to examine the potential of EIFS as a cost-effective approach to achieving high R-Value walls in existing residential buildings. To meet this objective, the following research questions were addressed:

1. What is the cost to perform a DER on exterior walls using various EIFS in residential applications?
2. What level of airtightness can be achieved with an exterior wall retrofit using an EIFS, recognizing that other components such as the ceiling, foundation, and windows will also contribute to air leakage?
3. Can prefabrication of EIFS wall panels reduce the cost and time for deep energy retrofits, and if so, by how much and under what circumstances?

1.4 Approach

To address the research questions, two demonstration sites were selected for an EIFS retrofit. Each site reflects a distinct type of housing construction within the residential housing market for which EIFS may prove a suitable energy efficiency solution:

- Central Islip, NY – Single-family detached home
- Saugerties, NY – Low-rise multi-unit apartment building

Criteria for selection of the demonstration sites were as follows:

1. Building Type: Selection of the EIFS demonstration sites was designed to capture a range of types and sizes of residential construction, with the intent of providing qualitative and quantitative insight into the logistics, performance, and cost-effectiveness of EIFS as a method for deep energy retrofit of existing residential buildings.
2. Location: Site eligibility spanned the entirety of New York State.
3. Elevation Characteristics: Simple elevations and geometric minimalism were key components of selection, as such sites limited the complexity of the EIFS, especially important for off-site fabrication of EIFS panels.
4. Use: Only buildings principally utilized for residential purposes were considered during site selection. Mixed-use buildings were also considered, provided residential use remained the primary function of the building.

Following determination of a suitable site, the sites were also screened to determine which were most likely to enable the research team to achieve the project goals. Additional screening criteria included

- Commitment to the project
- Readiness to move forward (i.e., schedule)
- Availability of funds
- Location relative to project partners
- Characteristics of the building relative to the target characteristics
- Existing condition of the building
- Potential for publicity and dissemination

Additionally, buildings where the exterior siding was to be replaced or repaired were ideal candidates as the cost of the siding could be discounted from the overall retrofit cost. While two sites were completed, many others went through the screening processes and were not selected or dropped out. Section 6 of this report describes some of these sites and the barriers encountered in attempting to conduct these DERs.

2 Demonstration Projects

2.1 Central Islip

One single-family detached home was retrofitted using site-applied four-inch-thick EIFS. Site-specific details were developed as required. The 2×4 wall cavity was filled with blown-in cellulose as part of the overall retrofit project. Site work and costs of the EIFS were documented. Costs for a comparable off-site fabricated panel system were estimated with the assistance of panel fabricators. Envelope leakage was measured before and after EIFS application.

2.1.1 Site

The case study site was a single-family detached frame home in Central Islip, New York. Basic characteristics of the home are provided in Table 1 and photographs of the pre-retrofit home are provided in Figure 2.

Table 1. Central Islip Existing Building Characteristics

Building Type	Single-family detached home
Conditioned Floor Area	2,200 ft^2
Foundation	Full unconditioned basement
Structure	2x4 wood frame
Gross Wall Area	2,122 ft^2
Net Wall Area	1,680 ft^2
Exterior	Vinyl siding—retrofit to 4-inch EIFS
Height	Two stories above grade

Figure 2. Front and rear elevations of the pre-retrofit home

2.1.2 Site-Applied Exterior Insulation and Finish System Application

Off-site panelization and on-site fabrication were both considered for this project. On-site fabrication was chosen because the small scale of the project would have made setting up to produce panels cost prohibitive.

The first step in EIFS installation is to install the bottom track (Figure 3). The bottom track serves to protect the edge of the EIFS and to assist in aligning the EPS panels during installation. It includes provisions for drainage.

Figure 3. After scaffolding is set up, a bottom track is attached to the base of the sheathing to accept the bottom of the EIFS

Next, a liquid water resistive barrier (WRB) is brushed onto the sheathing; a layer of reinforcing mesh is embedded into the coating at the sheathing joints (Figure 4). Overhangs at eaves were removed and added back on over rigid insulation to match the 4-inch EIFS thickness. At the gable ends, the roof deck was extended where necessary to match the 4-inch EIFS depth. A metal drip edge was added to direct water away from the rake.

Figure 4. The water resistive coating is brushed onto the sheathing with a layer of reinforcing mesh embedded at sheathing joints

An approximately 12-inch wide strip of reinforcing mesh is left hanging at all four sides of the window openings (Figure 5). It will later be wrapped around the edges of the EPS panels, protecting them at all exposed edges. This obviates the need, in standard installations, for any additional window trim to be built out to the thickness of the added EIFS, thus eliminating a step required for other wall insulation retrofit techniques that use built-up insulation and siding.

Figure 5. Reinforcing mesh is affixed around the newly installed windows

After the coating is complete, more reinforcing mesh is affixed around the newly installed windows; it will be used to wrap the edges of the insulation.

Sections of EPS insulation, 4-inches thick and measuring 2×4 ft, are adhered to the walls. Where necessary, the backside of the panels are rasped to conform to irregularities in the substrate wall. The EPS joints are smoothed out (Figure 6). Smoothing the joints between EPS foam panels is essential for getting an even finish coat that avoids telegraphing joint lines.

Figure 6. Smoothing joints between EPS panels

An additional one-inch thick by four-inch wide layer of EPS is used to form window trim (Figure 7). This was done primarily for aesthetics, but also to help improve R-value in an area where wall cavity insulation is compromised by additional framing. Other applied shapes can be used to create architectural forms as desired.

Figure 7. EPS used to form window trim

The gray basecoat is troweled on over an embedded layer of reinforcing mesh, which provides a durable surface (Figure 8). Additional layers of mesh can be added to increase impact resistance. The basecoat is applied over the formed window trim and edges of the EPS panels, embedding the yellow mesh around windows and other penetrations (Figure 9).

Figure 8. The gray basecoat is troweled on over an embedded layer of reinforcing mesh

Figure 9. Basecoat is applied over window trim and edges panels

The basecoat is applied over the formed window trim and edges of the EPS panels, embedding the yellow mesh around windows and other penetrations

The final step is to apply the finish coat, which includes the color and texture. The material arrives in pails and is first mixed and then troweled on (Figure 10). The final product is shown in Figure 11.

Figure 10. The finish coat is mixed and applied with trowels

Figure 11. The finished system

2.1.3 Labor Breakdown

The application occurred in winter, a challenging time for EIFS, which requires dry weather and outdoor temperatures above 40°F for 24 hours after application. Out of 19 non-holiday days during the EIFS application process from December 14, 2012 to January 10, 2013, eight days were lost due to weather (either cold temperatures or rain). The total labor was 278 hours over 11 days. Gross wall area (including fenestration) was 2,122 ft^2 and net wall area (excluding fenestration) was 1,680 ft^2. Gross ft^2per labor-hour were 7.6 and net ft^2per labor hour were six.

If this system were panelized off site, site labor would be reduced, as no base or finish coating would be necessary on site. Prep and water barrier labor would remain the same; however, the remaining tasks would be replaced by installation of the panels and the sealant joints. Total site labor for this home with off-site panelization might be 140–180 hours. Labor hours were logged for each major step in the process. Table 2 shows the labor breakdown. Note the labor hours shown here do not include time to remove and replace roof eaves and extend roof deck over gables, which would have been unchanged regardless of panelization.

Table 2. Labor Breakdown

Step	Description	Labor Hours
Prep Work	Set up two-story scaffold around entire house and install base track at bottom termination	28
Water Resistive Barrier*	Brush on liquid-applied coating with embedded mesh reinforcement at sheathing joints	40
EPS Board	Adhere 2-ft x 4-ft x 4-inch thick EPS boards and smooth joints; form window trim and cut drip edges	103.5
Base Coat*	Trowel on liquid-applied base coat with mesh reinforcement	53
Finish Coat*	Trowel on 2-layer finish coat (single layer finish coats are an option and would take approximately one half the time)	53.5
Total	-	**278**

* These steps require dry weather and outdoor temperatures between 40°F and 100°F for 24 hours after application.

2.1.4 Economic Modeling

The Central Islip case study home was modeled using Version 2.0.0.6 of the National Renewable Energy Laboratory-developed Building Energy Optimization (BEopt™) energy and cost analysis software. BEopt modeling looks at costs and energy consumption over a long-term project analysis period (30 years in this case). During that period other components of the home, particularly equipment, may be replaced when they reach their end of lifetime. BEopt incorporates the costs and benefits (in the form of improved efficiency of the new equipment) of these normal replacements into the long-term analysis. The annualized energy-related costs of the retrofit are the initial retrofit costs, plus the future replacement costs, and the costs of operation (energy) averaged over the analysis period.

BEopt was first used in optimization mode to identify the retrofit measures that were cost effective (i.e. result in lower annualized energy-related costs). BEopt optimization curves were generated for two scenarios considering EIFS retrofits. The primary variable provided in BEopt was EIFS thickness (2-inch, 4-inch, and 6-inch), with a reference case of vinyl siding. The complete list of variables is shown in Table 3. The optimization was run with two reference cases: mid-priced vinyl siding at \$4 per ft^2 and high-end vinyl siding at \$7 per ft^2 (materials and labor). Siding was assumed to be at the end of its 30-year lifetime at the time of the retrofit. Other economic modeling assumptions are provided in Table 4. Vinyl siding costs are based on local prices obtained from the project general contractor. EIFS costs are based on actual project costs for 4-inch thickness and manufacturer estimates for other thicknesses.

In optimization mode, BEopt runs multiple cases with various combinations of energy measures over the 30-year analysis period. It then plots the annualized energy-related cost of each case against the percent source energy savings compared to the reference case (in these cases, replacing vinyl siding only). Each point on the plot represents one case. The curve developed along the bottom of the points is the lowest-cost package of measures at a given percent energy savings. The optimal point (lowest overall annual energy related costs) is the bottom of the curve. The reference case is shown on the Y-axis at 0% energy savings. Each possible combination of retrofit measures was compared to each reference case, resulting in one plot for each reference case (Figures 12 and 13).

In the analysis with the midrange vinyl siding reference case (Figure 13), the optimal point includes 4-inch EIFS, ceiling insulation, and air sealing. While this package is the optimal retrofit of the options analyzed in terms of annualized energy-related costs, it is higher in cost than replacing the siding with midrange vinyl alone (increase of $333). However, compared to high-end vinyl, the EIFS package has a lower annualized energy-related cost (decrease of $28) as shown in Figure 14.

Table 3. Optimization Options

Measure Considered	Capital Cost	Selected
Mid-Range Vinyl Siding	$9,673	Reference A
High-End Vinyl Siding	$16,928	Reference B
2-inch Thick EIFS	$31,510	No
4-inch Thick EIFS	$32,719	Yes
6-inch Thick EIFS	$33,928	No
R-38 Fiberglass Batts Ceiling Insulation	$1,214	Yes
Air Sealing to 2 ACH50	$6,152	Yes
R-5 Whole-Wall Basement Insulation	$1,901	No
Double Pane Vinyl Windows	$13,594	No

Figure 12. BEopt optimization curve with midrange vinyl siding reference

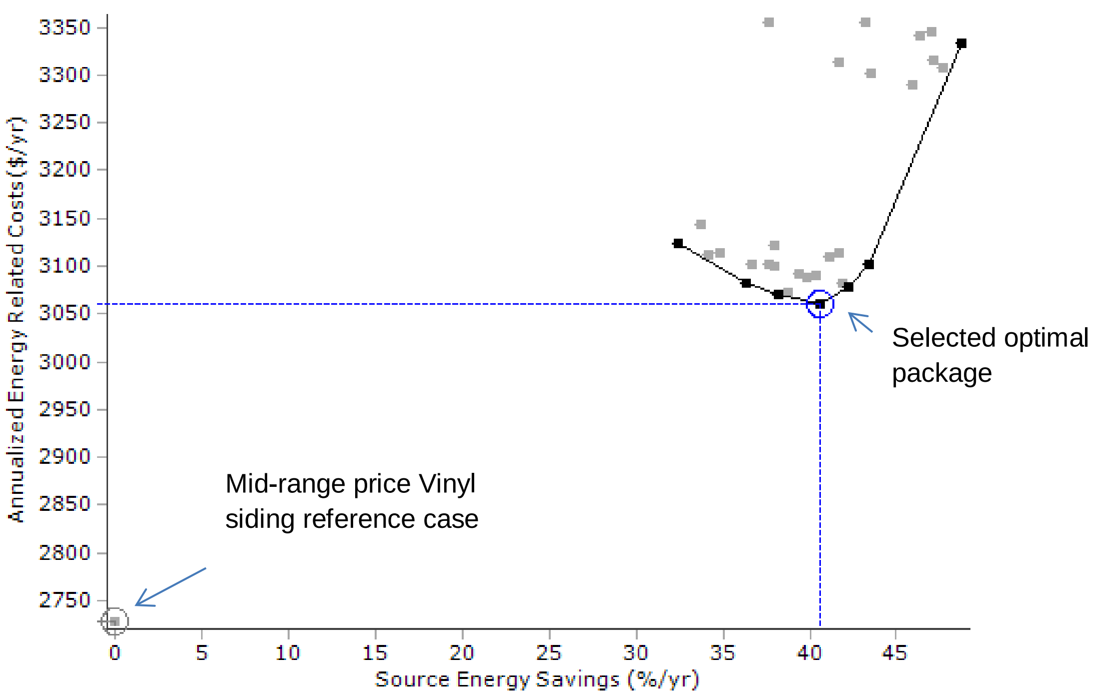


Figure 13. BEopt optimization curve with high-end vinyl siding reference

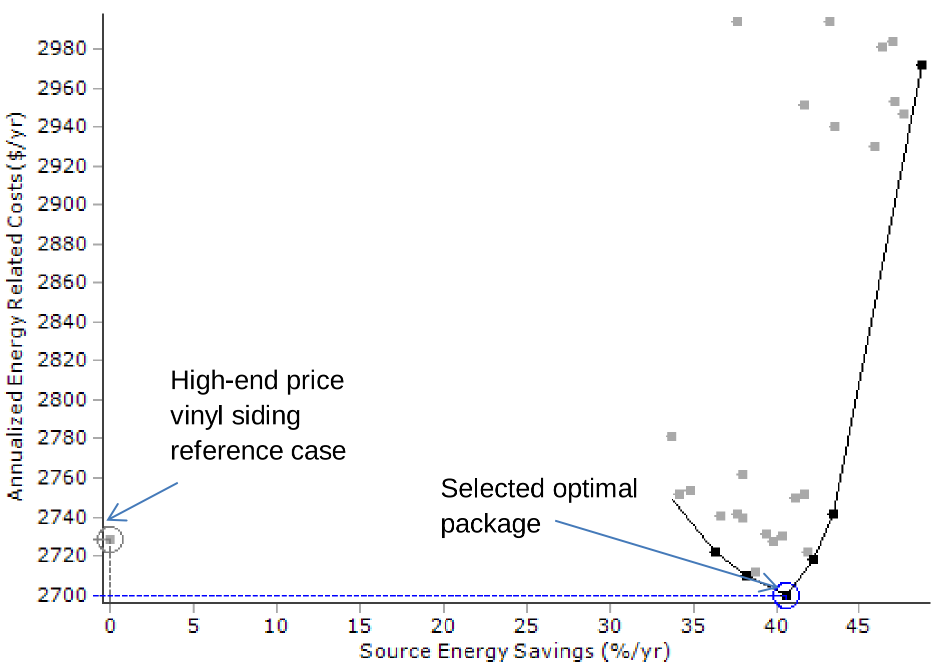


Table 4. Optimization Modeling Assumptions

Economic Variable	BEopt Input
Project Analysis Period	30 years
Inflation Rate	3.0%
Discount Rate (Real)	3.0%
Loan Interest Rate	7.0%
Loan Period	5 years

Following the optimization analysis, a BEopt design-mode analysis was completed including only the EIFS walls, ceiling insulation, and air sealing because these were the three items deemed “cost-effective” in the BEopt optimization analysis. Cost effectiveness of an energy efficiency measure is defined as having a lower annualized energy-related cost as compared to not implementing the measure. A post-retrofit enclosure air tightness of 2 ACH50 was used for the EIFS cases (case study house test result), compared to the 15 ACH50 pre-retrofit case.

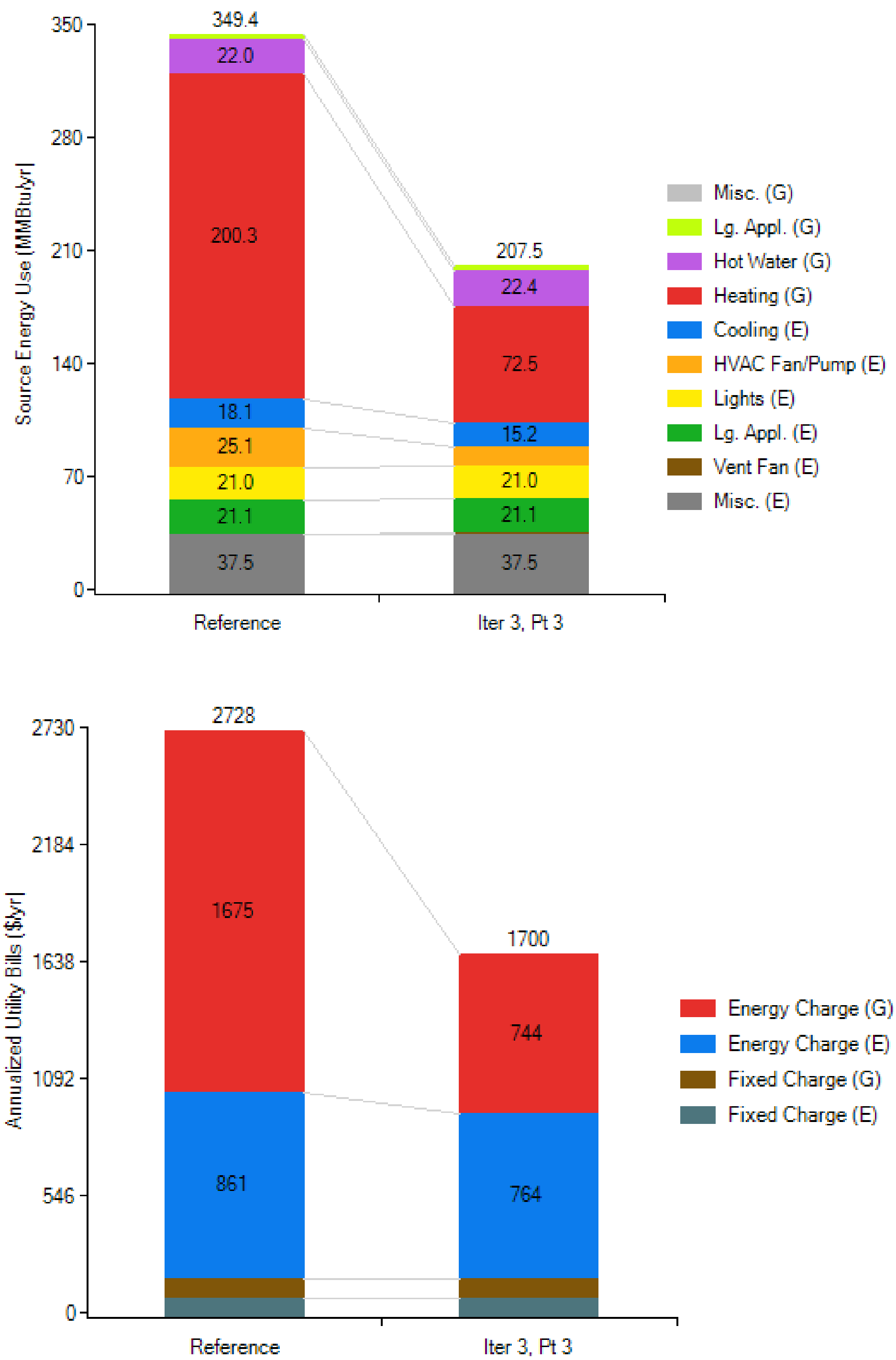
The major modeled characteristics of the house, including capital costs of the initial retrofit measures, are described in . Note that these measures are not necessarily reflective of the actual house retrofit; typical generic measures were used for the model. Capital costs of items to be replaced in the future (at wear out) are not shown in the table because they would have to be incurred regardless of the initial retrofit.

BEopt annual energy and utility bill savings are shown in Figure 14. Annualized utility bill savings are $1,028 (at $1.60 per therm and approximately $0.20 per kWh); source energy savings are 141.9 MMBtu/year. Carbon dioxide (CO_2) emission reductions based on the utility savings are 8.6 metric tons/year. In traditional economic payback terms, the incremental (compared to high-end vinyl siding replacement) ROI for the 4" EIFS/air-sealing/ceiling insulation package is 4.4% with a 22.5-year payback.

Table 5. Central Islip Model Characteristics

Measure	Pre-Retrofit	Post-Retrofit	Capital Cost at Time of EIFS Retrofit
Foundation	Unconditioned basement	No change	
Floor	R-19 fiberglass batts	No change	
Exterior Walls	R-7 batt, grade III	Add 4-inch EPS insulation as part of EIFS (R-16)	$32,719 (offsetting cost for new vinyl siding)
Windows	Single pane clear, non-metal frame	Double pane clear vinyl at wear out	
Ceiling	R-19 fiberglass batts	R-38 fiberglass batts	$1,214
Infiltration	15 ACH50	2 ACH50	$6,152
Ventilation	Exhaust	No change	
Heating	Gas 72% AFUE furnace	78% AFUE furnace at wear out (10 years from start of analysis)	
Air Conditioning	10 SEER	13 SEER at wear out (nine years from start of analysis)	
Ducts	R-6 in attic and basement	No change	
Lighting	Benchmark	No change	
Water Heating	Gas Standard	No change	

Figure 14. BEopt modeled source energy savings and utility bill savings



2.1.5 Utility Bill Analysis

Pre-retrofit utility bills were not available for the Central Islip house. Post-retrofit bills were collected for one year and compared to the energy model predictions (Table 6). Several questions were raised by the utility bill analysis:

- Electric usage is about 3.5 times the predicted amount. Given that the home is owned by a non-profit and used as a residence for five single men, the higher occupancy would be expected to lead to higher electric consumption.
- Furthermore, electric consumption dramatically increases in proportion to the heating load, despite the fact that the heating system installed in the house is a natural gas fired furnace.
- Winter gas usage is lower than predicted by the model for space heating.
- Electric usage would be expected to increase in summer with air conditioning, however this is not the case. Electric use is lower in summer than would be expected. The 644 total cooling degree days in 2014 (Albany) were lower than surrounding years (644 compared to 744 for 2013 and 894 for 2015), but still higher than the normal (550). Presumably air conditioning was sparingly used, if at all.
- According to the home specifications and inspections of installed equipment, the only natural gas end use is the space heating boiler (water heater is a heat pump). Nevertheless, there is gas use of about 10 therms per month year-round. The source of this gas use is unknown.

These anomalies were brought to the attention of the developer and owner/operator of the home. According to them, the use of electric space heaters in homes of this occupancy type has been an ongoing problem. Residents do not have access to the central thermostat and they resort to space heaters to exercise individual control. It is unclear why summer cooling energy is so low and the reason for the summer gas use is unknown.

To compare the enclosure efficiency of the as-built building to the REM/Rate model, the weather normalized utility bills were compared to the predicted annual heating load. Heating energy consumed was calculated as the sum of electric and gas heating energy. Monthly electric heating energy was estimated by subtracting the electric baseload (average of the lowest usage months of June–September) from the given month. Gas heating energy was calculated similarly. The results of this analysis are also provided in Table 6. The load calculated from the utility bills is 39.9 MMBTU per year as compared to the modeled 44.8 MMBTU per year. These loads are quite similar, considering that a slightly lower actual load is expected because of the higher occupancy-driven internal gains. This analysis does demonstrate the efficiency of the envelope, despite the poor utilization of the mechanical equipment in this house.

Table 6. Central Islip Utility Bills and Heating Load Comparison

Electric Time period	Electricity (kwh)	Gas (therm)	Elec heat*	Gas heat* (therm)	Heat MMBTU	HDD actual	HDD normal	MMBTU adjusted
11/25/2013–12/30/2013	1,988	48	1,522	36	8.8	826	836	8.9
12/30/2013–01/29/2014	1,510	72	1,044	58	9.4	1123	1008	8.4
01/29/2014–02/27/2014	1,196	71	730	57	8.2	938	861	7.6
02/27/2014–03/29/2014	912	56	446	43	5.8	866	713	4.8
03/29/2014–04/29/2014	1,002	36	536	24	4.2	412	392	4.0
04/29/2014–05/30/2014	694	21	228	10	1.8	88	136	2.7
05/30/2014–06/26/2014	327	10					16	
06/26/2014–07/30/2014	384	10					1	
07/30/2014–08/30/2014	596	9					1	
08/30/2014–09/29/2014	558	11	92		0.3	14	40	0.9
09/29/2014–10/29/2014	648	10	182		0.6	166	249	0.9
10/29/2014–11/26/2014	1,004	10	538		1.8	579	524	1.7
12-month TOTALS:	10,819	364	5,316	336	41	5,012	4,777	39.9
REM/Rate Heating Load								44.8

* Estimated as described

2.2 Saugerties

A multi-family building was retrofitted using an off-site panelized EIFS. Site-specific details were developed as required for the retrofit application. The EIFS thickness was 4 inches and covered 4,500 ft^2 of wall. The windows were also replaced as part of the overall retrofit project. Site work and costs of the EIFS were documented. Envelope leakage was measured before and after EIFS application to assess the impact of the EIFS on infiltration.

2.2.1 Site

The site in Saugerties, NY is a 12-unit, two-story affordable housing apartment building. Walls are 2x4 wood frame with 1.5 inches fiberglass batt insulation in poor condition; the lower floor has brick cladding; the upper floor has vinyl siding. Apartments are entered directly from the outside at grade level or along an elevated walkway on the second floor. All apartments are through-building, meaning they can be entered from either side of the building. At the onset of work, the building was fully occupied. Apartments are heated and cooled by individual through-wall heat pumps in each apartment. Water heating is via a central system with heat generated by solar thermal panels and supplemented by a gas fired boiler. Previous energy retrofit measures completed in September 2012 include mechanical equipment replacement, air sealing, crawl space floor insulation, ceiling insulation, and PV system. Notably, the previous retrofit did not address windows or walls, because the owner did not have a cost-effective solution despite their poor thermal performance. Because the building is master metered, and the building owner pays for all utilities, the owner was highly motivated to implement energy efficiency measures, as demonstrated by the previous retrofit.

Table 7. Saugerties Existing Building Characteristics

Feature	
Building Type	12-unit affordable multi-family
Conditioned Floor Area	5,040 ft^2
Foundation	Crawlspace
Structure	2x4 wood frame
Exterior	Brick veneer first floor, vinyl siding second floor
Height	Two stories above grade

Figure 15. The pre-retrofit building

2.2.2 Panelized Exterior Insulation and Finish System Application

The project demonstrated the application of a pre-fabricated (panelized) and pre-finished wall insulation system for exterior application on existing residential construction. The system, known as Sto-Lite, is comprised of an expanded polystyrene core covered with an exterior insulation and finished system (EIFS). It is fabricated into panels off-site and adhered to the exterior of a building (to sheathing or masonry) using a combination of mechanical fasteners and adhesive. The simple building geometry and repeated façade patterns were thought to make this building suitable for off-site panelization of the exterior wall insulation system.

Siding on the second floor was removed. The brick on the first floor remained. The EIFS panels cover both floors: over the first-floor brick cladding and over the second-floor plywood sheathing. Potential thermal bridges at the brick window sills, jambs, and heads were also covered with EIFS panels. Panels were attached with adhesive plus mechanical fasteners through channels let into rear of panels (not thru the insulation). The final finish appearance is EIFS over the entire building’s walls with caulk joints approximately every four to eight feet. Appendix B illustrates the major construction details used to apply the EIFS.

The gable end roof overhang was built out to protects the EIFS panels from weather and prevent moisture from infiltrating behind the panels, reducing the likelihood of moisture-related structural and indoor air quality issues (Figure 16).

Figure 16. The chimney was removed, and roof extended to accommodate panels

The second-floor walkway deck planks were trimmed back. If left in place, the deck planks would have resulted a thermal bridge along the length of the building between the two floors. By trimming the planks back, the EIFS ran continuously behind the deck, resulting in an uninterrupted thermal barrier. The deck joist against the building was moved out approximately four inches so that the panels could fit behind and remain flush at joints and seams (Figure 17).

Figure 17. Decking was cut back, and joist moved away from the building

At the first-floor masonry, all brick protrusions were chiseled back, creating a level surface upon which to install the EIFS. Existing vinyl siding and weather-resistive barriers were removed from the second-floor, exposing the exterior sheathing beneath. Prior to the full application of the liquid WRB, a separate coating, embedded with reinforcing mesh, was brushed into the sheathing joints, as was done at Central Islip (Figure 18).

Figure 18. Brickwork and vinyl siding

Protruding brickwork at first floor is notched back and vinyl siding at second floor is removed

A liquid water-resistive coating was applied to the entire building to prevent moisture from soaking through the brick and entering the interior wall assembly. Once the coating dried, gaps in the brickwork from the chipping of protrusions were filled with spray foam (Figure 19).

Figure 19. The liquid-applied water-resistive barrier is applied and gaps are filled with spray foam

The nature of the retrofit process necessitated on-site modification of the panels at uneven or protruding portions of the building facade, such as window sills. This was necessary to allow electrical wiring to run through the panels at existing light fixture locations. Therefore, the panels and façade were carefully measured prior to application (Figures 20 and 21).

Figure 20. Fitting Panels

The panels are field-notched to ensure an adequate fit around fenestration and other difficult areas

Figure 21. Notches are cut with a circular saw and adapted to fit protrusions using a boxcutter

When applying the adhesive, all trowel notches were made vertically to allow water behind the panels to drain down and exit near the bottom of the wall. Having a way for the water behind the panels drain helps avoid moisture-related issues. In this building decking at the first-floor and eaves at the second-floor provide additional moisture protection (Figures 22 and 23).

Figure 22. Panel adhesive is mixed on-site and applied with a notched trowel

Figure 23. The lightweight panels are lifted into place by hand and pressed to the wall

Each panel was prefabricated with metal tabs that can be modified to extend approximately three-quarters of an inch from the edge of the panel and screwed in place. This allows for provisional panel support during the adhesive curing period (Figures 24 and 25).

Figure 24. Panels are temporarily held in position while the adhesive sets using screws

Figure 25. As panels are applied, they are scrutinized to ensure a close, level fit

Installation of the foam backer rods ensures a continuous thermal barrier by sealing gaps between the panels. Masking tape was applied to the panels prior to caulking to avoid damaging the aesthetics of the panels (Figure 26).

Figure 26. Foam backer rods are installed at seams and sealed with caulk

Panels were installed across the entire building, including the solar PV closet and solar thermal tank enclosure to produce a uniform thermal barrier and appearance across the entire building façade (Figures 27, 28, and 29).

Figure 27. The process continued around the building to create a continuous thermal boundary

Figure 28. Following installation of the panels, the roof extension is shingled and finished

Figure 29. The finished system

2.2.3 Labor Breakdown

Initial prep work for the project began in November 2013 with the removal of the chimney, extension of the roof, and preliminary removal of protruding brick. Work was halted for the winter, but did not resume until September 2014.

Labor hours for the project totaled 1,044 over approximately four months. The project was completed by a primary labor crew consisting of three workers. Gross wall area (including fenestration) was 3,588 ft^2 and net wall area (excluding fenestration) was 2,736 ft^2. Gross ft^2per labor hour were 3.4 and net ft^2per labor hour were 2.6. Labor hours were logged for each major step in the process. Table 8 shows the labor breakdown.

Table 8. Labor Breakdown

Step	Description	Labor Hours
Prep Work[1]	Demolish chimney; remove siding; chip protruding bricks; extend roof at east and west elevations; cut back deck	324
Water Barrier*	Brush on liquid-applied coating (gold coat) with embedded mesh reinforcement at sheathing joints	48
Panel Installation/ Sealant	Adhere 4in. EIFS boards; install backer rods; *caulk joints; site adjust panels	672
Total		**1044**

* These steps require outdoor temperatures above 40°F for the duration of the drying process (Sto Corp., 2011)

Weather delays stymied progress at the site, as did unforeseen logistical issues. Staggered panel deliveries inadvertently created worksite lulls, as the speed of the labor crew occasionally surpassed the panel delivery timeline. On-site measurements for panel prefabrication took place on multiple occasions, sometimes obstructing the work flow of the installation crew. Erroneous measurements of gable dimensions led to panels with exaggerated slopes, necessitating an additional visit from a Sto representative for new measurements and adding time for the production of properly sized panels. Panels occasionally arrived without mounting clips to hold the panels in place while the adhesive set,

1 Prep work is not directly related to the type of exterior insulation retrofit, as these tasks would be required in order to apply any exterior insulation system involving rigid boards and added wall thickness.

necessitating their creation on-site. Lastly, as the project neared completion, under-estimate of the amount of caulk necessary for the project and sub-freezing temperatures caused further delays, as the crew waited for the caulk delivery and for adequate installation temperatures. Many of these issues can be avoided by scheduling installations to avoid cold months, and by more precisely coordinating material delivery.

2.2.4 Modeling

The Saugerties building was modeled using Version 14.6.3.1 of NORESCOs REM/Rate energy analysis software. Pre- and post-EIFS models were run using a whole building model to explore the retrofits effects on space heating and cooling loads and annual energy demand.

REM/Rate modeling examines annual energy consumption and cost data. Both the pre- and post-retrofit models include additional recent retrofit measures (new mechanical equipment and ceiling insulation) undertaken at the property in September 2012. Assumptions regarding other REM/Rate input components (such as lighting and appliances) remain constant across both sets of models. The new windows were also placed in both models. Differences arising within the models therefore emerge solely from the improved thermal resistivity and reduced air infiltration provided by the EIFS.

Because the building does not have a common corridor, each apartment is entered separately from an outside walkway on each floor. Therefore, whole building leakage could not be tested easily. A sampling strategy was utilized with blower door tests conducted in half of the units. At first, guarded blower door tests were conducted on the same four apartments before and after the retrofit to determine the leakage to outside; however, the guarded testing was determined to be unreliable due to highly connected interior spaces. Unguarded leakage tests were conducted on the six units at the eastern end of the building, averaged and then scaled up to the entire building to obtain an estimate of overall leakage and leakage reduction. Using this method, pre-retrofit leakage was estimated at 9,368 cfm50 and post-retrofit leakage was estimated at 8,454 cfm50, a reduction of 11% due solely to the EIFS. The major characteristics of the building are described in Table 9.

Table 9. Saugerties Model Characteristics

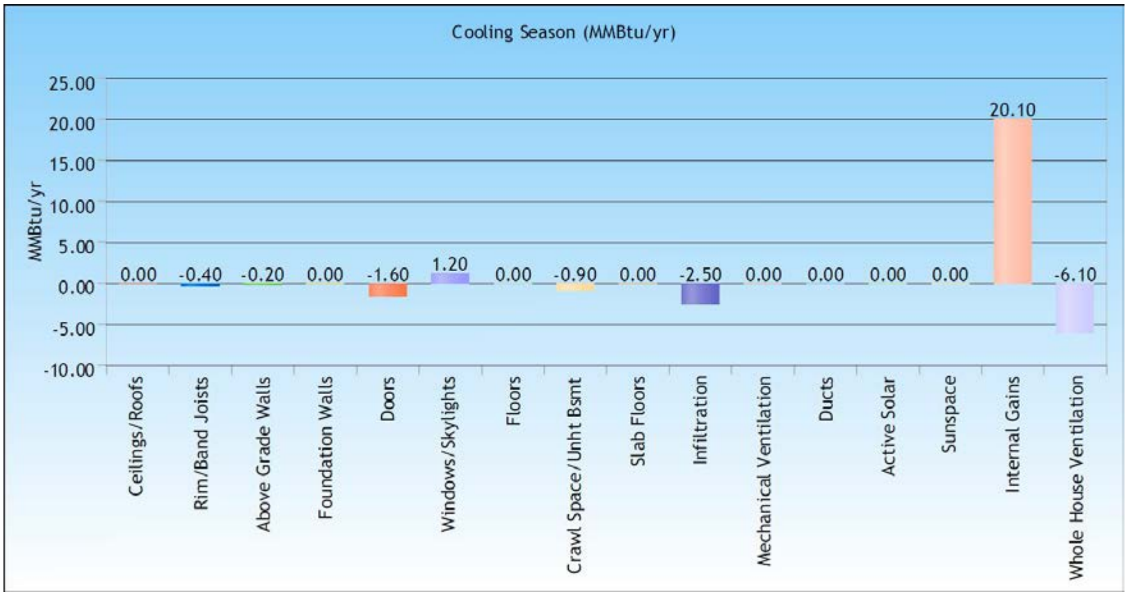
Measure	Pre-Retrofit	Post-Retrofit
Foundation	N/A	N/A
Slab Floor	Uninsulated	No Change
First Floor Above Crawl Space	Uninsulated	No Change
Exterior Walls	R-4, Grade III fiberglass batt insulation	Add 4-inch EPS insulation as part of EIFS (R-15.2)
Windows	U-0.30, SHGC-0.24	No Change
Ceiling	R-50, 5/8'' sheetrock on wood truss with 6'' fiberglass batt insulation and 16'' cellulose insulation	No Change
Infiltration	9,368 cfm50	8,454 cfm50
Ventilation	None	None
Heating	3.50 COP Amana Packaged Terminal Heat Pump	No Change
Air Conditioning	11.7 EER Amana Packaged Terminal Heat Pump	No Change
Ducts	None	None
Lighting	10% fluorescent	No Change
Water Heating	Central with .95 EF gas water heater	No Change

The results of the REM/Rate analysis are shown in Table 10 for the whole building. Consumption by component is shown in the graphs in Figures 30 and 31.

Table 10. Saugerties Model Results—Annual Site Energy Consumption in MMBTU

	Pre-Retrofit	Post-Retrofit
Heating energy	88.6	57.1
Cooling energy	9.6	10.3
Baseload	283.4	283.4
Total	381.6	350.8

Figure 30. Component Consumption Pre-retrofit



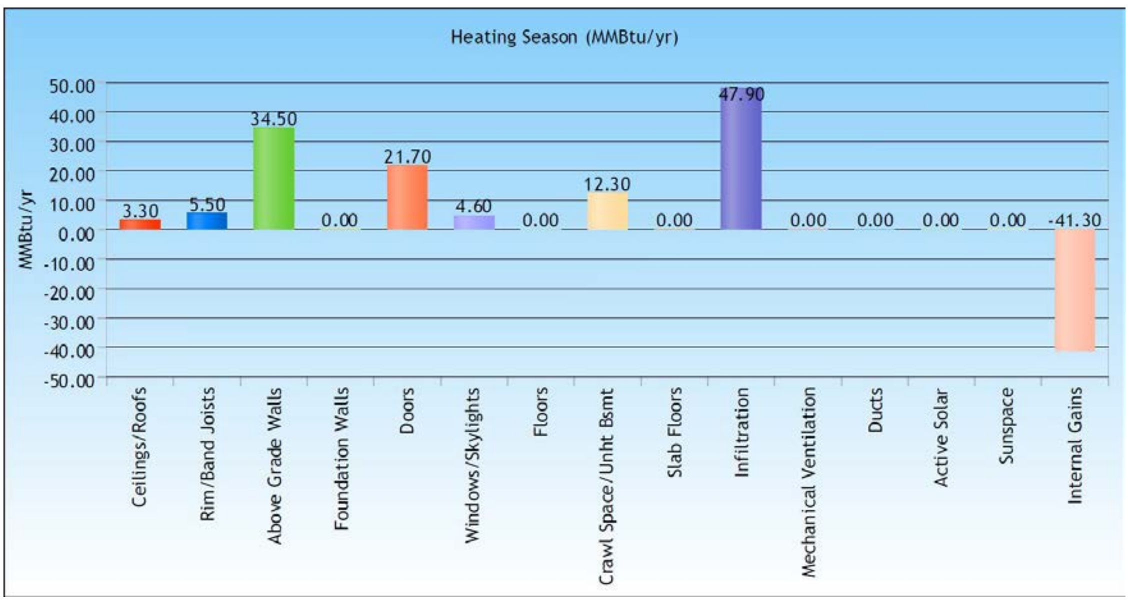
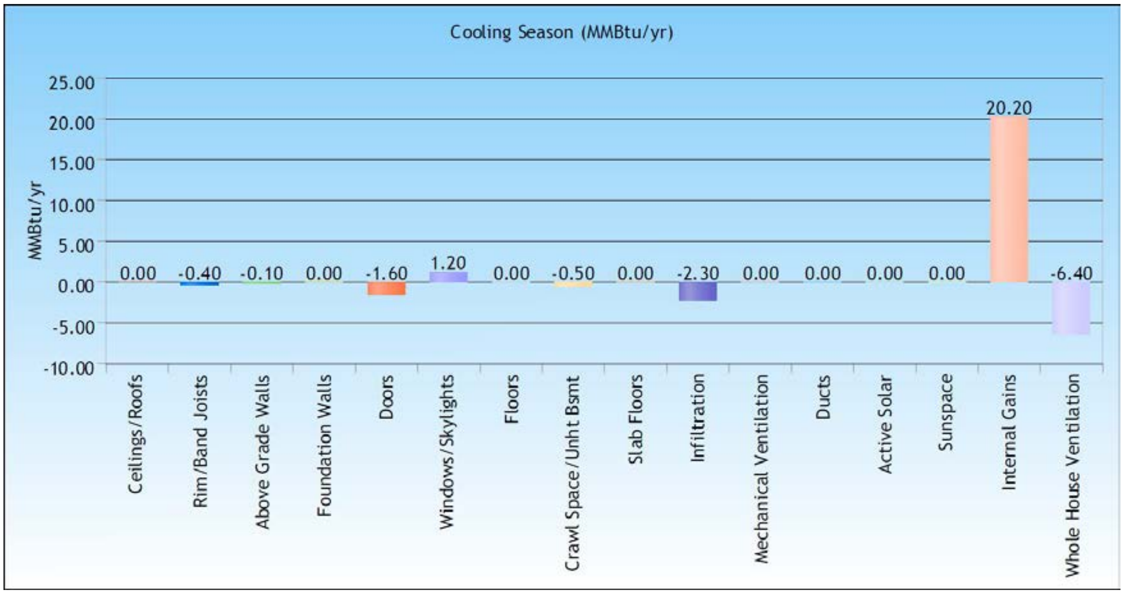
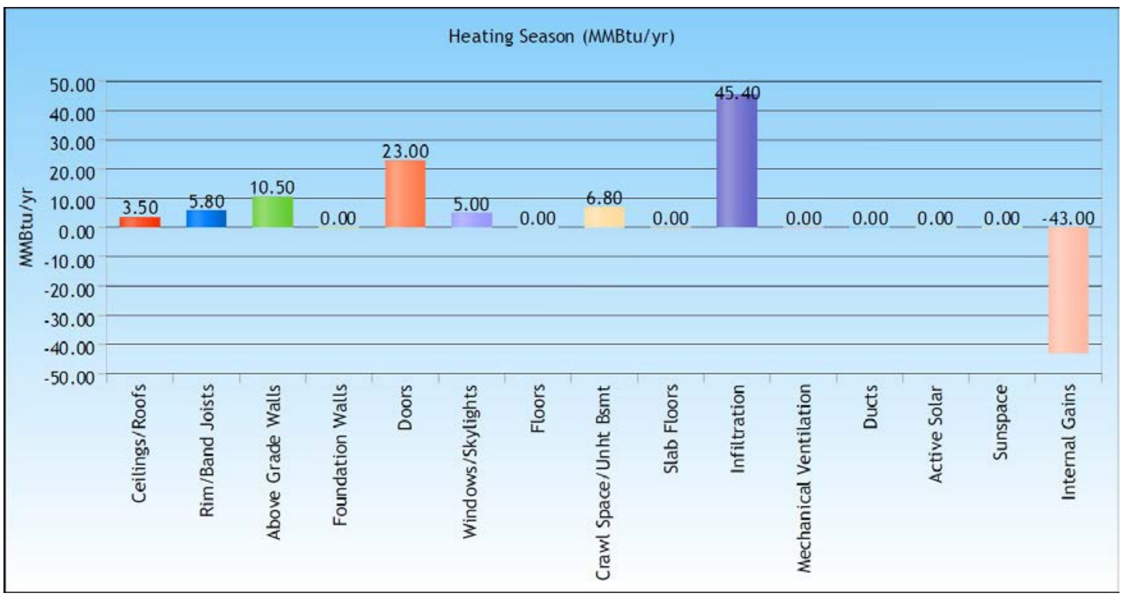


Figure 31. Component Consumption Post-retrofit





2.2.5 Utility Bill Data

Utility bills from Saugerties were compared before and after the retrofit. Note that windows were also replaced between the pre and post-retrofit utility bill periods.[2]

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2 Old windows were wood frame single pane double hung and awning windows in generally poor condition; new windows are vinyl double hung with a U value of 0.30.

Figure 32. Saugerties Utility Bill Analysis (square symbols for pre-retrofit; diamond symbols for post-retrofit)

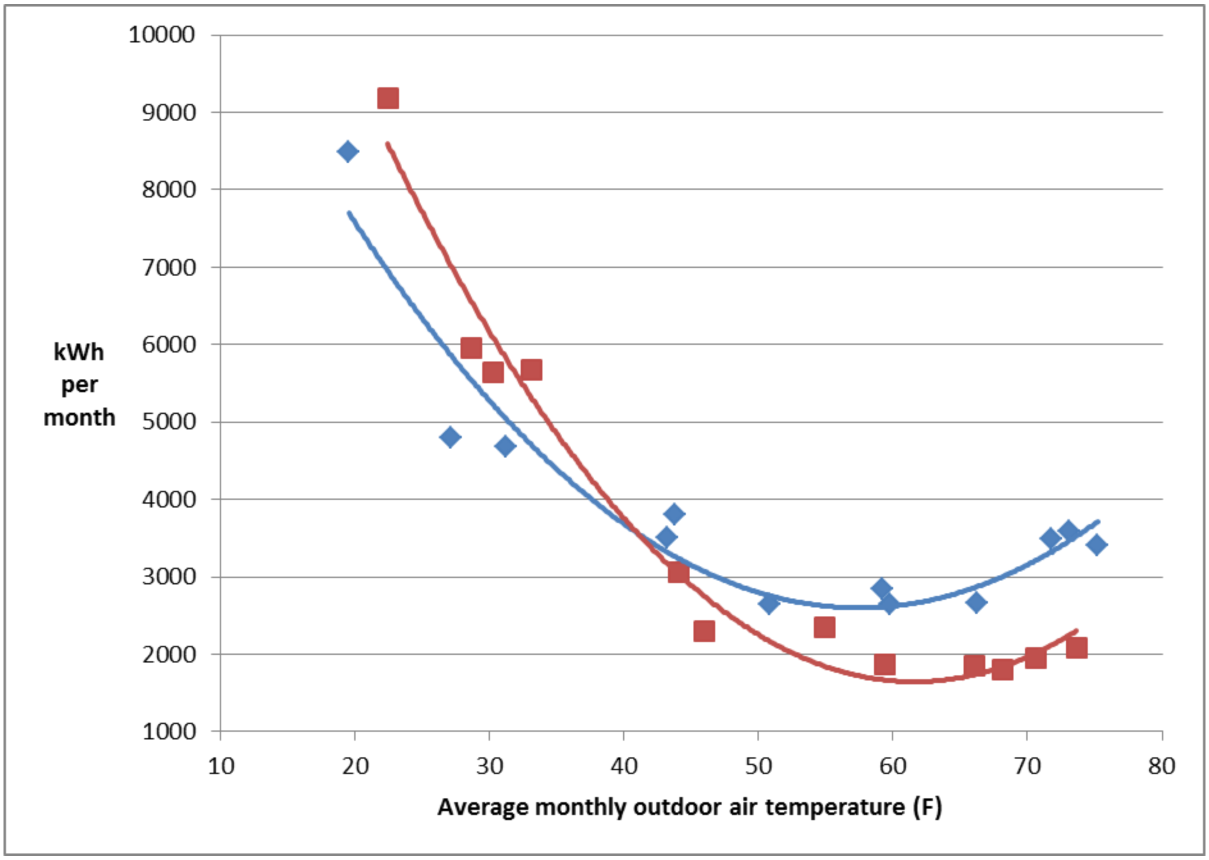


Figure 32 plots the total building energy use against average monthly outdoor temperature. At temperatures below 40°F post-retrofit energy consumption (blue curve in graph) was lower. At temperatures above 40°F the post-retrofit energy consumption was higher—during the non-heating season energy consumption increased by about 800 kWh per month). Cooling energy in this climate is negligible, so this increase is likely due to higher occupancy in the post-retrofit period and significant vacancy was observed during the pre-retrofit period. Figure 33 isolates the peak heating months; at these colder temperatures the post-retrofit case shows an approximately 20% energy reduction. However, adjusted for the higher occupancy-driven baseload (Figure 34), heating energy savings as calculated by the regression equation is 44% (Table 11), which is close to the 47% simulated savings previously mentioned. Cooling energy increased by 278%, resulting in a total space conditioning energy savings of 36% or 7,803 kWh.

Figure 33. Saugerties Utility Bill Analysis primary heating months only (square symbols for pre-retrofit; diamond symbols for post-retrofit)

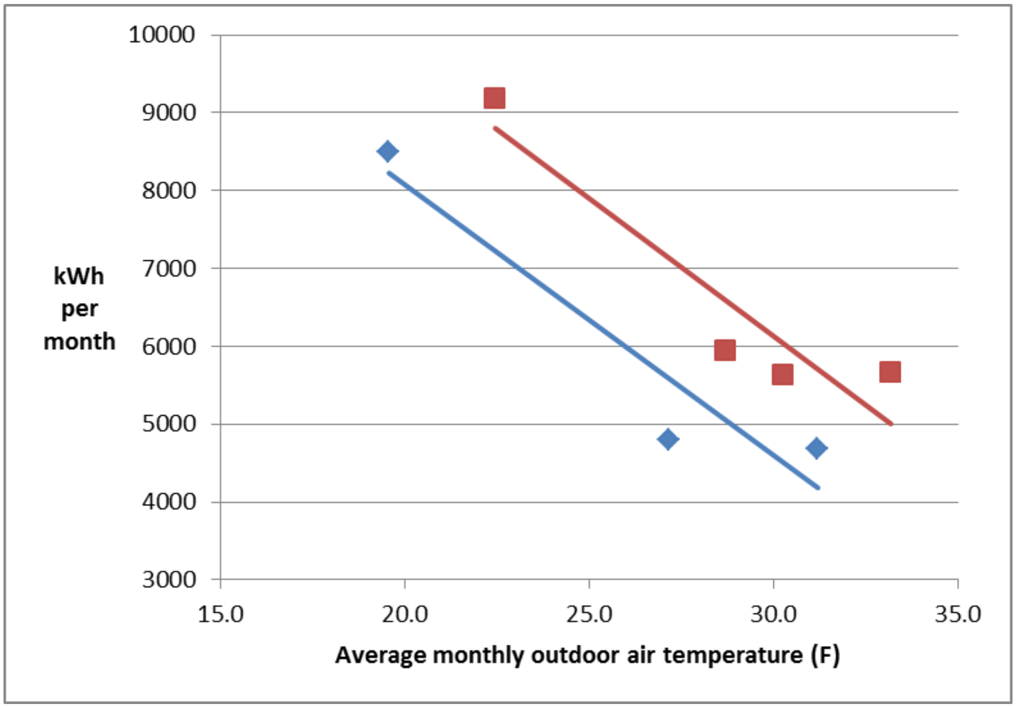


Figure 34. Saugerties Utility Bill Analysis adjusted for baseload (square symbols for pre-retrofit; diamond symbols for post-retrofit)

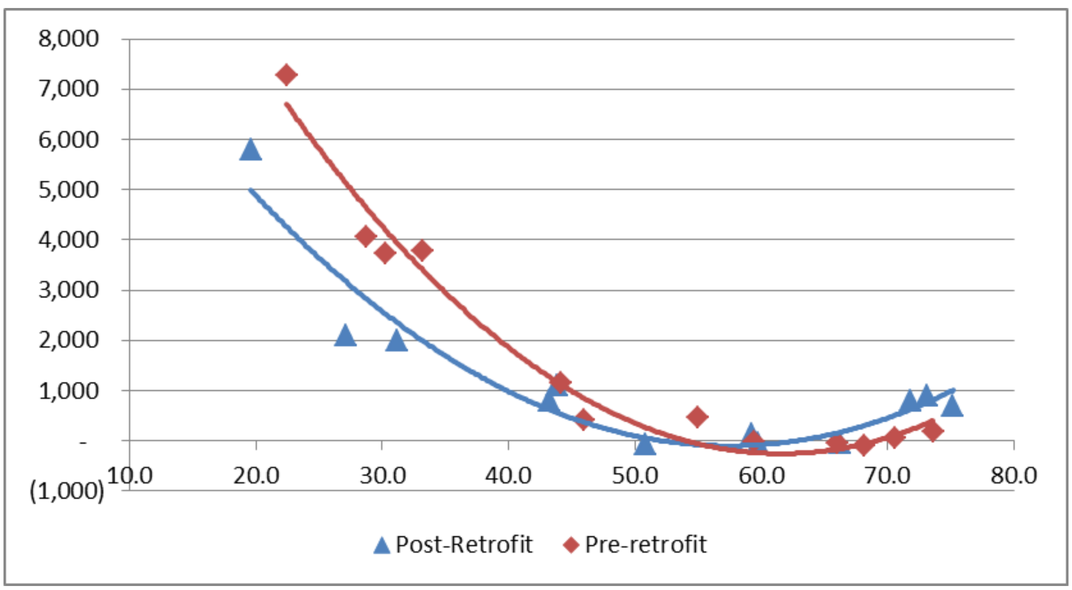


Table 11. Saugerties Normalized space conditioning energy from utility bills

	Normalized kWh	% Change
Pre Heat	20,925	
Post Heat	11,689	
Pre-Cool	516	
Post Cool	1,950	
Delta Heat	(9,236)	-44%
Delta Cool	1,433	278%
Delta Combined	(7,803)	-36%

2.2.6 Economics

Total project costs were $72,166, with about half ($36,194) being EIFS materials and the remainder labor and miscellaneous costs due to the installation contractor. For this amount, the building owner received several benefits including a new look to help improve marketability, a new weather resistive barrier to improve durability, and presumably, improved thermal comfort. Annual energy savings is estimated at $1,170 based on 7,803 kWh and a rate of $0.15 per kWh. Looked at solely from an energy savings point of view, the economics (61-year payback; 1.6% ROI) are not favorable; this project would only be desirable if achieving the other benefits previously listed were important to the building owner. This analysis includes the cost of the siding in the retrofit; i.e., it assumes the siding was not at the end of its lifetime and did not need to be replaced. If the siding were in need of replacement and the cost of mid-range vinyl siding is deducted (assuming it would be installed over the brick on the lower floor and replace the existing vinyl on the upper floor), then incremental costs would be $56,413, payback would be 52 years and ROI would be 1.9%.

2.2.7 Sensor Data

To quantify the effect of EIFS on equipment run-times, temperature data was collected on-site at several key indoor and outdoor locations. Data were collected during similar calendar periods for two heating seasons (Figures 35 and 36). The first season occurred during the pre-retrofit stage, from early January to mid-February 2014. Similar data was collected for late January to mid-February 2015, following the

EIFS installation. Temperature data was collected every 10 seconds from the PTHP refrigerant coil, the PTHP electric resistance backup element and ambient. These data illustrate how often and for how long the heater ran to maintain setpoint. Residents were requested to leave the heat pump programmed to a stable set point temperature throughout the data collection period.

Both the pre- and post-EIFS heating seasons showed frequent operation of the heat pump. A comparison of the cycle times in apartment 6 is presented in Table 12, Figures 35 and 36. On- and off-cycle times are shown in relation to the ambient outdoor temperature. Average on-cycle time for the post-retrofit period was less than half that of the pre-retrofit period, despite colder average temperatures during the post-retrofit period. Off-cycle times were approximately 30% briefer on average in the post-retrofit period. One possible explanation from this data is the superior thermal envelope during the post-retrofit period resulted in the room warming up faster than in the pre-retrofit period. It is unknown why the off-cycle period would have been shorter.

Table 12. Saugerties unit 6 heater average cycle times

	ON	**OFF**		
Period	**Average cycle time in minutes**	**Average cycle time in minutes**	**Avg. outdoor temperature (F)**	**Avg. indoor temperature (F)**
Post retrofit (1/28/15–2/11/15)	7.0	17.9	17.5	74.4
Pre-retrofit (1/3/14–2/12/14)	18.0	20.9	19.5	75.0

Figure 35. Saugerties unit 6 heater on-cycle time

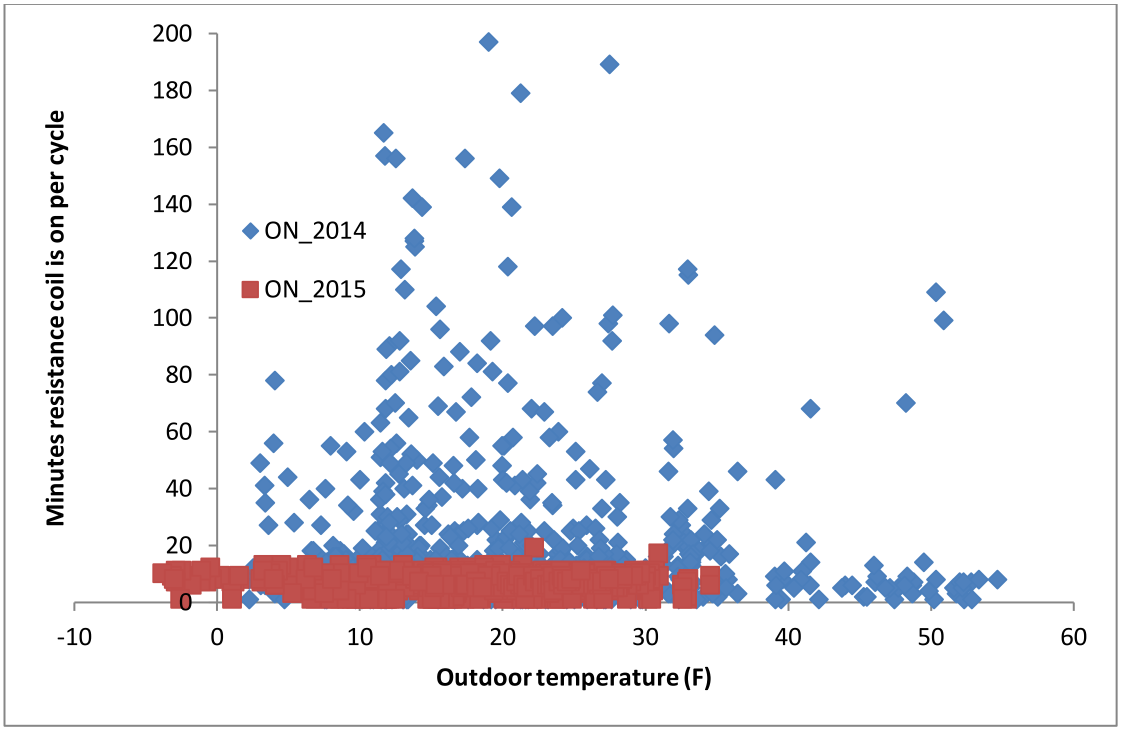
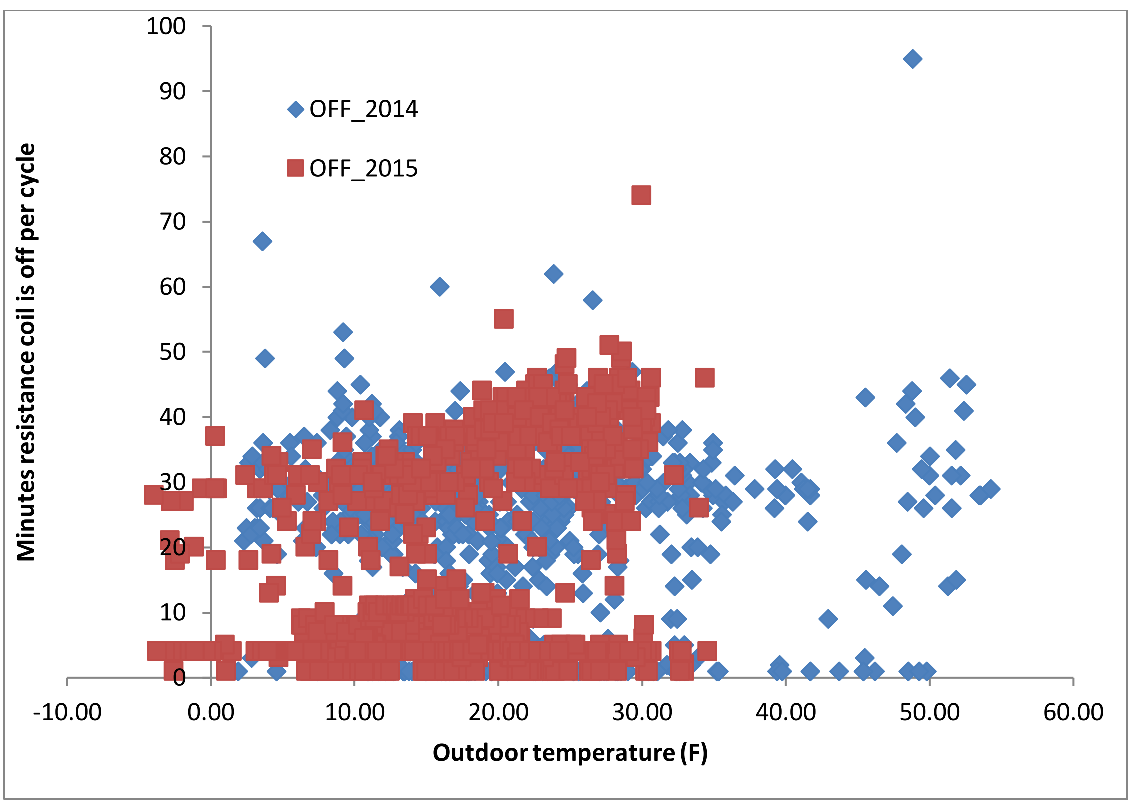


Figure 36. Saugerties unit 6 heater off-cycle time



3 Discussion

The following sections discuss the risks, selection criteria, interactions with other building systems, cost, performance, and other aspects of using an EIFS in a deep energy retrofit.

3.1 Performance Compared to Program Goals

The original goals of NYSERDA Proposal Opportunity Notice 2254 “Building Envelope Strategies for Advancing Deep Energy Retrofits” were to demonstrate exterior insulation systems that met the following objectives:

- Air barrier and sealants to provide total envelope air leakage level < 0.25 CFM 50/ssf (shell square footage)
- Provide whole wall assembly (excluding windows) insulation value of R > 25
- Field implementation (material and labor) cost less than $10/ssf

The Central Islip project demonstrated that site installed EIFS systems can meet this air leakage criteria. The 2 ACH50 final test result converts to 0.11 CFM50/ssf. Note that the EIFS surface area represented less than one third of the total shell area with the balance being basement area, fenestration and ceiling area. The Saugerties building was not as tight, coming in at an estimated 0.91 CFM50/ssf. Because of the building configuration, it was not feasible to test the entire building as a whole; whole building leakage was estimated based on a sample of guarded blower door tests, which may have introduced significant error into this estimate. Nevertheless, it is likely the ceiling and floor of this older building, which were not air sealed in this retrofit, were large sources of leakage.

In both cases, R-16 was added to existing insulated 2x4 walls, resulting in total wall R-values in excess of R-25.

Total costs exceeded the $10 per square foot target by 50-100%, demonstrating the challenge of driving down costs on projects that are each unique. This is discussed in greater detail later in this report.

3.2 Site and Safety Risks

EIFSs do not require special site safety precautions beyond general construction site precautions such as ladder safety, personal protection (goggles, hard hats, gloves) and other general Occupational Safety and Health Administration (OSHA) requirements. Some more specific cautions likely to apply to EIFS work include:

- Use proper scaffolding assembly and adequate fall protection to avoid putting workers at risk.
- Utilize eye protection and respirators when sanding EPS insulation to avoid breathing in EPS dust.
- Unlike stucco, EIFS work does not involve handling dry stucco mix that can become airborne creating a risk of inhaling airborne silica. EIFS coatings arrive at the site premixed in pails and are water-based.

3.3 Moisture Risks

Trapping moisture between two vapor/air barriers is a risk of all walls, including EIFS cladding applications if an interior vapor barrier exists and if there is not adequate ventilation through the drainage plane behind the EIFS insulation layer. To allow for drying of incidental moisture, EIFS assemblies should not contain interior vapor barriers or impermeable interior finishes. "An important exception to this latter requirement is where the drainage plane is also a vapor impermeable air barrier membrane and the interior framing cavities are uninsulated" (Lstiburek, 2007). Drying ability will be enhanced with adequate ventilation through the drainage plane. Note the drainage plane indicated in the details provided in the Appendix.

In addition, as previously discussed, bulk water must be managed; face-sealed approaches that rely on exposed sealants do not provide acceptable rain control or durability and are very risky (Lstiburek, 2007).

3.4 Code and Regulatory Issues

In most jurisdictions fire codes permit EIFSs for most building types and conditions if they have been tested and approved. Generally, noncombustible details must be used at roof areas. This means that instead of plastic base track at roof setbacks and penthouses metal flashing must be used in conjunction with pre-backwrapping (to 6 in.) of the EPS insulation with basecoat and mesh.

Zoning ordinances may limit the extension of the building footprint beyond lot lines and past setback distances caused by the addition to wall thickness. The additional footprint area may cause a building to exceed the maximum floor area limits if such limits exist. Some jurisdictions are removing these barriers; for example, New York City recently revised laws to remove certain of these restrictions for energy retrofits (Urban Green Council, 2012).

3.5 Trade Resources

Although EIFSs are not new, they may be new to the local residential construction industry and local EIFS applicators may be unaccustomed to working on small-scale residential retrofits. There may be a learning curve as applicators figure out their cost structures for these new project types. Additionally, certain retrofit-specific details may need to be disseminated among applicators who are accustomed to new construction projects.

Applicators familiar with prefabricated lightweight panel systems are even rarer. Because the market for this system is small, it may be difficult to get multiple bids and competitive pricing in many areas.

3.6 Maintenance

EIFSs require periodic (approximately every five years) inspections and possible maintenance to ensure sealant joints are intact. This is especially important for panelized systems that will typically have many more joints than field-applied projects. For large buildings, factory-certified inspectors are available to do this work. On smaller low-rise buildings, an EIFS applicator can do the inspection. Cleaning also may be required (similar to other siding products) depending on the finish selected.

3.7 Durability and Reliability

The primary concern most homeowners will have when considering EIFS is the performance of the system in shedding water. Faulty system design and installation practices can cause problems with any cladding system; therefore, careful attention to waterproofing details is essential to long term durability. EIFSs with a moisture barrier and drainage plane behind the insulation can adequately protect the wall. The Appendix provides details showing one approach to achieving this design objective. Maintenance, as previously discussed, is important to ensure durability.

3.8 Occupant Comfort, Health, and Safety

The overall effect of adding exterior wall insulation is to improve comfort conditions for building occupants, compared to the pre-retrofit wall assembly with high air leakage and little or no insulation. The added layer of continuous insulation provides a thermal break that reduces the heat flow rate through framing members and/or masonry and leads to more stable interior temperature conditions.

The exterior insulation also should result in a quieter indoor environment. Furthermore, less outside air infiltration will result in less dirt and dust leaking into the home. However, if the resulting home is too tight, mechanical ventilation may need to be added with a commensurate energy penalty.

The Central Islip house was vacant prior to the retrofit so no pre-post retrofit comfort comparisons could be made. In Saugerties, a survey of residents was conducted during which they were asked about comfort and behavior before and after the retrofit. The results of the survey, which was conducted as a series of one-on-one interviews by the property manager, are provided in Table 13. They indicate a dramatic improvement in comfort as a result of the retrofit; additionally, most residents reported reducing the settings (lower in heating and/or higher in cooling) on their heating/cooling unit.

Table 13. Saugerties Resident Survey Results

APT	Winter thermal comfort		Summer thermal comfort		Operation of heating/cooling unit		Do you use any auxiliary heating or cooling?	
	After	Before	After	Before	(1) Leave on, constant setpoint (2) Only turn on when home (3) Employ unoc. setbacks		After	Before
	1= poor; 5 = excellent				After	Change		
1	4	2	4	2	1	None	no	no
2	4	1	5	1	2	Lowered setting	no	no
3	5	3	5	3	1	None	no	no
4	5	2	5	1	2	Lowered setting	no	no
5	5	2	5	2	1	None	no	no
6	5	1	4	2	3	Lowered setting	no	no
7	5	1	5	2	1	Lowered setting	no	no
8	5	1	5	1	2	Lowered setting	no	no
9	5	1	5	1	3	Lowered setting	no	no
10	5	2	5	2	1	Lowered setting	no	no
11	5	1	4	2	3	Lowered setting	no	no
12	4	2	5	2	2	Lowered setting	no	no
Avg.	4.8	1.6	4.8	1.8				

3.9 System Interactions—Enclosure

Retrofitting with EIFS has implications for new or existing windows, doors, and other exterior wall penetrations. The overall wall thickness will increase by the thickness of the EIFS. EIFSs can accommodate either an "innie" (window located at original wall surface) or "outie" (window moved to the new outer wall surface). If windows or doors are being replaced at the time of the retrofit, then a choice can be made to leave them in the existing location at the original wall surface (innies) or relocate them to the new outer wall surface (outies). For an outie configuration, new framing must be installed around the opening to support the window. Most masonry projects will retain an innie configuration because attaching framing to support the new window location is impractical. An outie configuration is more costly to build (both for the exterior framing and wider interior trim), but allows for more robust waterproofing details. Regarding aesthetics, innies will create recessed windows from the outside, outies will create deep window pockets on the interior.

Work may also be necessary to adjust roof overhangs to maintain an acceptable extension over the wall outer surface and to maintain clearance for soffit vents (Kosny, Fallahi, & Shukla, 2013).

3.10 System Interactions—Equipment

When adding a continuous layer of insulation to an exterior wall assembly, the overall R-value of the wall assembly will increase, reducing heating and cooling loads. This may result in the need for smaller capacity heating and cooling equipment, reduced ductwork, and if severe enough, potential redesign of the heating, ventilation and air-conditioning (HVAC) system. The overall effect is likely to reduce costs if equipment is being replaced. If equipment is not being replaced, it may result in oversized equipment that could result in problems such as short-cycling or overheating unless HVAC system controls are altered to compensate.

3.11 Application Alternatives

When considering an EIFS retrofit, several options are available related to waterproofing, finishes, thickness, and fabrication.

3.11.1 Waterproofing

Building wrap or a liquid-applied water resistive barrier may be used as the waterproofing layer and drainage plane. Liquid-applied barriers are thought to perform better, but often cost more on residential-scale projects. Also, the use of building wrap would render impossible the use of an adhesively bonded insulation layer and instead dictate mechanically fastened insulation. Mechanically fastened installation is quicker, especially in retrofits of older buildings where the sheathing may be out of plane because the insulation does not have to be sanded on the backside to lie flat; rather, the fasteners pull it close to the sheathing. However, fasteners put many more holes in the water resistive barrier.

Mechanical fasteners have been known to cause aesthetic problems. When the temperature difference between the interior and exterior of a house increases (during extreme cold or heat), the increased rate of heat loss or gain through the fasteners can become visible as condensation or frost that adheres to the exterior of the stucco where the fasteners are located. This causes an effect called ghosting. Over time, sections of wall that are damper tend to collect more dust from the air, and as a result, the ghosting becomes permanently etched in the wall surface. Eliminating this effect, as well as improving the overall thermal performance of the wall system, provides additional motivation to consider the adhesively applied system.

3.11.2 Finishes

Many finish colors and other options are available from EIFS suppliers. Most basic finishes are one coat. Upgrade finishes that are intended to resemble stone or brick are often two coats and may involve stenciled patterns.

3.11.3 Fabrication

EIFSs, while traditionally field applied, may also be fabricated off-site into panels prior to installation on the building. Advantages of a panelized approach include:

- Less dependence on warm, dry weather for construction. For example, about 40% of the EIFS application time for the Central Islip case study project was lost due to weather-related work stoppage.
- Less debris on-site including packaging, pails of liquid materials, and most significantly, EPS debris and dust that results from rasping the backs of panels to fit on walls and at joints for site application.
- Reduced disturbance to building occupants during retrofits because of the shorter time on site.
- Potentially lower cost where site labor is expensive or working conditions are difficult.

Disadvantages of off-site fabricated panels include:

- The additional sealant joints between panels may require another trade and additional periodic maintenance. Sealant joint inspection is recommended every five years. Inspection and maintenance of sealant joints may be difficult for taller buildings that require scaffold drops for access.
- Smaller tolerance for site irregularities such as dimensional variation or out-of-plane walls that can be more easily accommodated with site fabrication.
- Higher costs for smaller projects where panels may require high degrees of customization.
- Fabricators and applicators capable of delivering the panelized system may be hard to find (further discussed in Section 5.4).

3.11.4 Thickness

EIFS thickness will be influenced by energy efficiency requirements and limited by practical issues such as detailing at openings, inside corners, and other locations. As little as one inch to as much as 16 inches is possible.

3.12 Cost

One goal of this project was to evaluate the cost of the EIFS (both site and off-site fabricated) compared to the traditional approach of multiple layers of rigid board insulation, strapping and siding, and building out fenestration openings.

Total material and labor costs for the Central Islip case study site were tabulated and are shown in Table 14. This cost includes the water resistive barrier, 4-inch insulation, and base and finish coats.

Table 14. Central Islip Site Costs

	Based on Gross Wall Area	Based on Net Wall Area (Deducting Fenestration)
EIFS Cost	$32,000	$32,000
Wall Area	2,374 ft^2	2,075 ft^2
Labor costs, assuming 278 hours x $25 per hour	$2.93	$3.35
Total Subcontract Cost per Square Foot (including labor, materials, overhead and profit)	$13.47	$15.42

Increasing the thickness of the EIFS would add little to labor costs. Based solely on the added thickness of the EPS, the additional cost would be \$0.20–\$0.35/ft^2 per additional inch of thickness.

Costs for the Saugerties case study are shown in Table 15. When labor costs are included, the panelized EIFS had a much higher cost per ft^2 than the site-applied. Reasons for the higher cost included labor to cut panels in around the PTHP units and exterior lights; notching the backs of panels around brick window jambs, head and sills; covering window and door returns with narrow, site-fabricated panel strips; covering the solar thermal tank shed with 2” thick panels and enclosing the solar thermal pipe chase.

Table 15. Saugerties Site Costs

	Based on Net Wall Area
Wall Area	3,825 ft^2
EIFS Materials Cost	$37,010
Material Cost per ft^2	$9.68
Site Labor Cost (not including prep)	$39,600
Site Labor Cost per ft^2	$10.35
Total Cost	$76,610
Total Cost per ft^2	$20.03

3.13 Energy Efficiency

The continuous layer of EPS insulation that is part of the EIFS enhances the thermal performance of the wall in every climate zone. When installed against a frame wall system, the continuous exterior insulation reduces the effects of thermal bridging. As a result, building owners will have lower heating and cooling costs. Energy savings as projected by the modeling previously described indicates that under certain conditions an EIFS retrofit can be cost effective (i.e., lower annualized energy related cost) if exterior cladding is in need of replacement. The specific return on investment will depend on the existing building condition, energy prices, heating/cooling equipment efficiency, retrofit characteristics, and the cost of the alternative cladding system. High fuel prices (e.g., oil heat rather than gas), cold climate, poorly insulated or leaky existing walls, and low retrofit costs (relatively simple geometry) will improve the cost effectiveness of an EIFS retrofit.

4 Barriers

This section of the report describes additional sites considered for the case studies and barriers encountered in attempting to conduct them. Approximately 65 buildings were considered as case study sites. The main reasons many of these prospects did not convert into sites were:

- Site conditions such as lot-line construction and limited access to façades
- Challenging façade features such as architectural details, fire escapes, overall complexity, etc.
- Financial obstacles due to large façade areas, resulting in high costs, but with low energy prices depressing return on investment

The owners of the buildings in Figure 37 expressed interest in participating in the demonstration program; however, these buildings have façades that contain extensive architectural detail and attachments—in this case fire escapes that cover the majority of the exposed area. Only an interior or wall cavity solution would work for these buildings.

Figure 37. Poor demonstration candidates due to intricate facades

The building in Figure 38 is a better candidate for the EIFS wall system. Approximately 80% of its exposed wall area is coated with plain concrete stucco with no ornamentation or insulation. The rear wall does have a fire escape, but that represents a small portion of the 80%. A major obstacle here is the difficult access to the work area. All materials would need to be lifted over the roof or through neighboring property, and the narrow sideyards would make work difficult, especially if equipment had to be kept on the subject building's side of the property line. These obstacles could be overcome, and often are managed when necessary repair work must be completed on the many buildings of this type; however, they significantly add to costs and contribute to making elective work such as an energy retrofit cost prohibitive.

Figure 38. Candidate building with difficult to access rear and side walls

The two buildings in Figure 39 would benefit from an exterior wall insulation retrofit and were presented as candidates. The structure on the left has a large blank sidewall area shown in shadow. The wall is uninsulated and unadorned and would be a simple retrofit with EIFS panels. However, it is built on the lot line and adding exterior panels would encroach into the neighbor's property. This is a common condition in New York City. The building on the right is in a suburban area and was slated for a significant retrofit. While very suitable for a site-installed EIFS, the geometry of the building is too complex to merit pre-fabricated panels.

Figure 39. Two candidate buildings that would benefit from exterior wall insulation

While many buildings were presented to the project team with physical attributes that made them difficult demonstration sites, others were physically suitable, but did not participate due to financial or other issues. For example, the building in Figure 40 would have been an ideal demonstration site. It has uninsulated masonry walls, a repetitive façade design that could easily be broken down into panel modules, easy access to all facades, and few site complications. Packaged terminal air conditioner penetrations were slated to be covered over, which could easily have been accomplished with panels and the wall retrofit could have been integrated into other planned renovation work, including window replacement. Nevertheless, despite being deemed cost effective the EIFS panels would have increased first costs and the owner was only concerned with a short-term financial horizon. For investors with a longer-term outlook, this would have been an attractive retrofit.

Figure 40. Ideal candidate building for retrofit

5 Conclusions

This research addressed the questions below, each relating to the capacity for EIFS to be used for exterior wall insulation retrofits.

1. **What is the cost to perform a deep energy retrofit on exterior walls using various EIFS in residential applications?**

Costs per net ft^2 ranged from $15.42 for the site applied system at Central Islip to $20.03 for the panelized system at Saugerties. The Saugerties panelized system costs accounted for approximately half for labor and half for materials. The site-applied system costs found in the literature were similar to the Central Islip costs, but panelized costs in Saugerties were about 25% higher. The costs cited in the literature for three-story brick homes with a field applied system were higher still—about $25 per ft^2—largely due to the costs of working higher off the ground. It is not known how much this type of structure would cost with *a* panelized EIFS.

Variance between site applied and panelized costs is impacted by several site-specific factors, including differences in project size and geometric complexity. The most significant increase in labor hours for the Saugerties project resulted from the on-site modification of panels, which was necessary for adequately mounting panels across the building façade due to unexpected variations in building dimensions, as well as to maintain electrical wiring pathways for exterior lighting. Although more difficult to quantify, the relative skill of the labor crews installing the systems is very important. The mechanics of installation are easily communicated to experienced construction crews and efficiency of installation undoubtedly depends, at least in part, on the familiarity of these crews with the intricacies of EIFS installation processes. The Central Islip application was by a specialty EIFS contractor with extensive experience. The Saugerties application was by an experienced general contractor with limited EIFS experience and no panelized EIFS experience. Similar to the future cost decreases for traditional exterior insulation retrofits projected by Building Science Corporation in Neuhauser, 2013, cost reductions can be expected for EIFS as its popularity increases, impacting the propensity for installation crews to perform timely, efficacious installations.

From these results, it is evident that EIFS can compete with traditional exterior-applied insulation retrofits in residential housing markets, under certain conditions. Success or failure of retrofits to meet acceptable costs parameters within the residential retrofit market will be determined by several factors, not the least of which will be building geometric complexity, EIFS installation experience of the labor crew, and whether existing siding requires replacement, thereby offsetting EIFS costs, and in the case of high-end vinyl and other similarly-priced siding options, lowering AERCs. These early results suggest that site-applied EIFSs may currently be less cost-prohibitive for residential applications than panelized systems. Further analysis of panelized EIFS is needed.

2. **What level of airtightness can be achieved with an exterior wall retrofit using an EIFS, recognizing that other components such as the ceiling, foundation, and windows will also contribute to air leakage?**

Variability in age, design, construction technique, condition, maintenance, and a host of other elements complicate determination of the true impact of an EIFS on the overall airtightness of a retrofit building. Leaky buildings will benefit more than moderately tight homes.

The Central Islip case study project went from a pre-retrofit leakage rate of 15 ACH50 to a post-retrofit blower door test of 2 ACH50, which is extraordinarily tight. However, because this was a gut rehab, not all the improvement can be attributed to the EIFS. While this is an indication of how tight an EIFS home can be, superior construction of the other components, such as the foundation, ceiling, and windows, contributed to the low air leakage test result.

At Saugerties, testing was conducted immediately before and after the EIFS panels were installed so that the difference in test results would be solely attributable to the retrofit. However, because of the building design and occupancy, it was difficult to obtain definitive leakage test results for all apartments; nevertheless, an overall reduction in air leakage due to the retrofit of 11% was estimated.

Note that most improvements in air tightness are likely the result of the liquid applied WRB, not the insulation/panels and the WRB may be used without insulation/panels to achieve similar air tightness.

3. Can prefabrication of EIFS wall panels reduce the cost and time for deep energy retrofits, and if so, by how much and under what circumstances?

Benefits of panelization include greater speed and schedule reliability that can potentially convert to cost savings, less dust and dirt on site that are a result of rasping backs of panels to fit on walls for a site-fabricated system, and greater safety because of less time on scaffolds and fewer trips around the building. Prefabricated panels may be less costly for certain projects under certain conditions such as in poor weather and/or where site labor costs are high or working conditions difficult. Prefabricated panels can be delivered to the site for approximately $\$8/ft^2$ (net panel area at 4 inches thick and with standard finishes). If proficient applicators can install the WRB and panels for under $\$6/ft^2$ then off-site panelization becomes a viable alternative to site-applied systems in most instances. However, in the Saugerties case study, higher site labor costs resulted in overall higher project costs than expected.

4. What energy savings does the EIFS retrofit provide?

EIFS provides continuous air, water, and thermal boundaries for retrofitted buildings, reducing annual energy consumption. Quantified efficiency gains resulting from EIFS retrofits were calculated using computer energy modeling software.

Annualized energy-related costs (AERCs) at Central Islip, which include initial retrofit costs, future replacement costs, and the costs of operation averaged over the analysis period, yielded projected savings of $1,028 for the combination of 4-inch EIFS with interior wall and ceiling insulation retrofits. This result was compared to two reference scenarios in which exterior cladding was replaced with either mid-range or high-end vinyl siding. AERCs were higher for the 4-inch EIFS compared to the mid-range vinyl, but lower than the high-end, indicating that some single-family homes may benefit from utilizing site-applied EIFS as an alternative to traditional siding options.

Pre- and post-retrofit energy models were generated for the Saugerties demonstration site. These models were compared based on single-year energy costs, not AERCs. Unlike Central Islip, the only difference between the pre- and post-retrofit models was the installation of the panelized EIFS and its effects on whole-wall thermal resistivity and infiltration. The modeled annual energy cost savings was $1,351, which represents an 11% total energy cost reduction and a 31% reduction on space conditioning energy.

Utility bills from Saugerties were compared before and after the retrofit. Note that windows were also replaced between the pre- and post-retrofit utility bill data were collected. These data, after adjustment for weather and a higher post-retrofit baseload (presumed due to higher occupancy) showed a 36% space conditioning energy savings (7,803 kWh) per year as a result of the wall retrofit and window replacement.

5. Were any changes in occupant comfort observed?

The Central Islip house was vacant prior to the retrofit so no pre-post retrofit comfort comparisons could be made. At Saugerties a was conducted that indicated dramatic improvement in comfort and reduction in heating set points.

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Appendix A - Saugerties Details

Figure A-1. Typical panel joint detail over brick

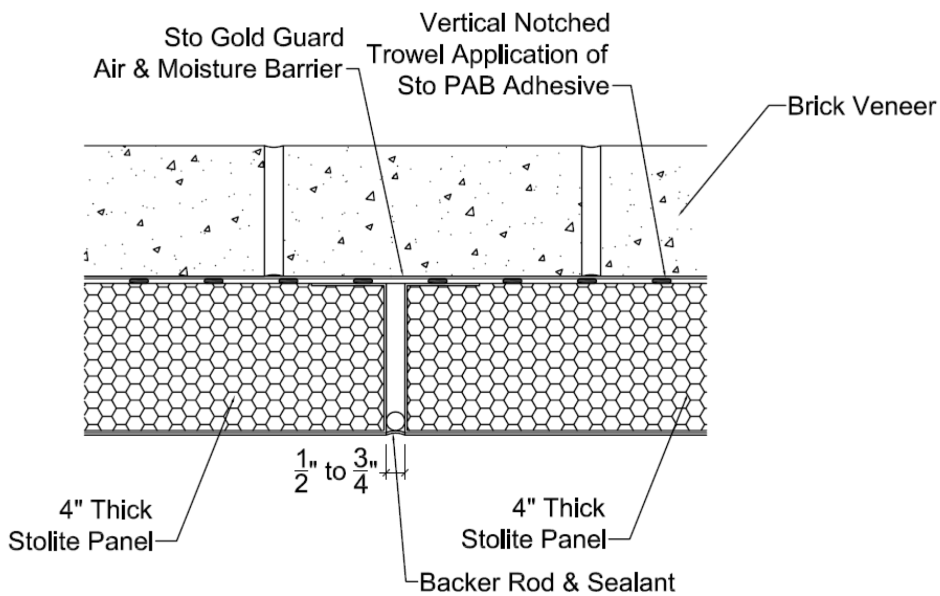


Figure A-2. Termination at sidewalk / patio

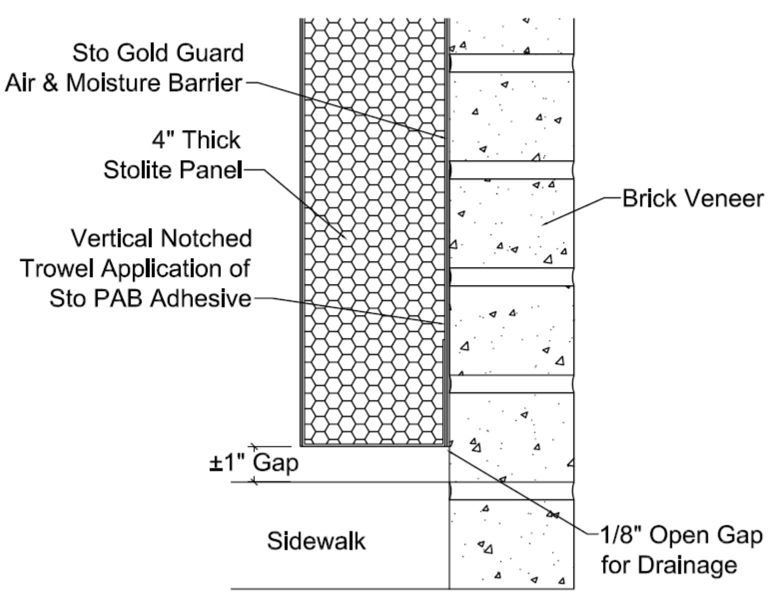


Figure A-3. Window / Door head return with drainage weep detail

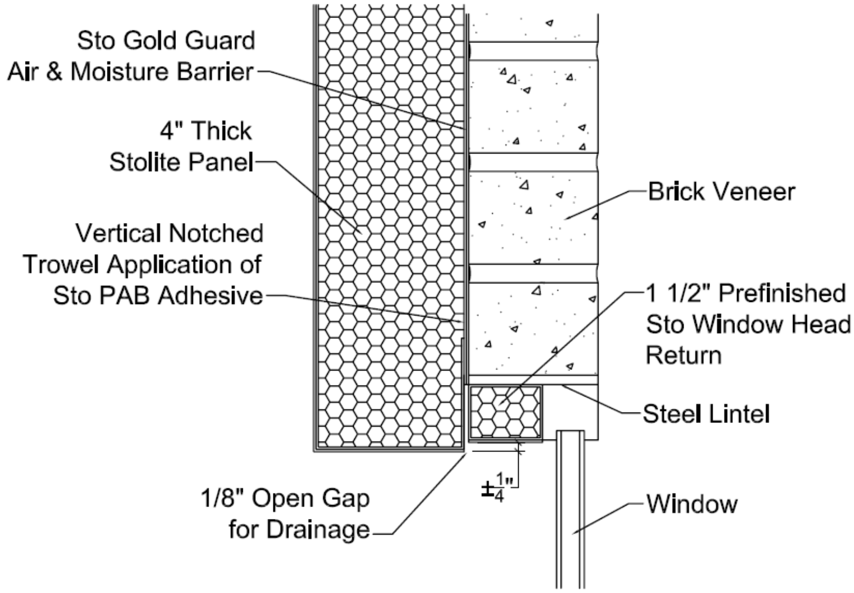


Figure A-4. Window / door jamb return detail

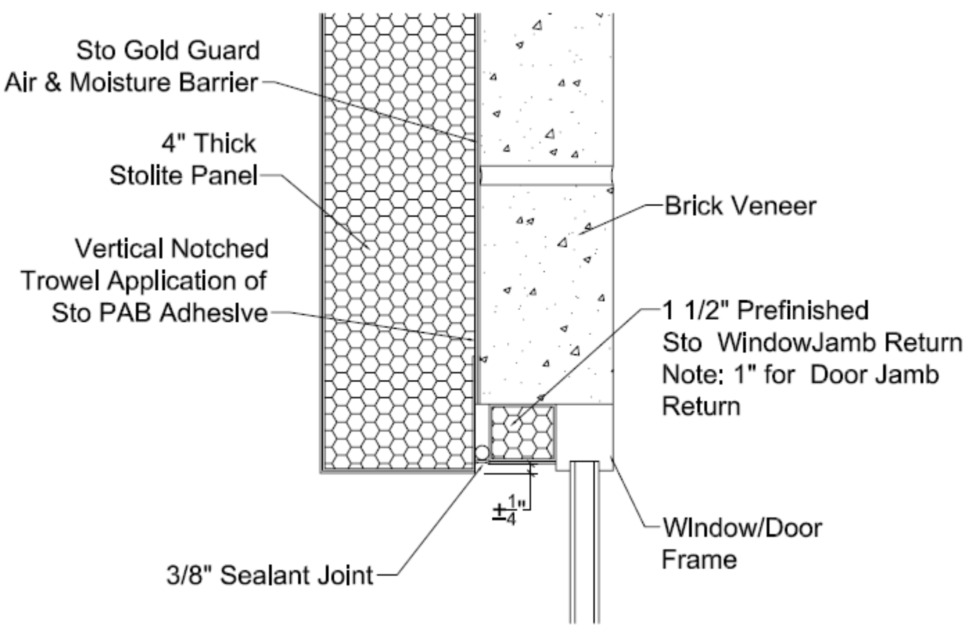


Figure A-5. Window sill

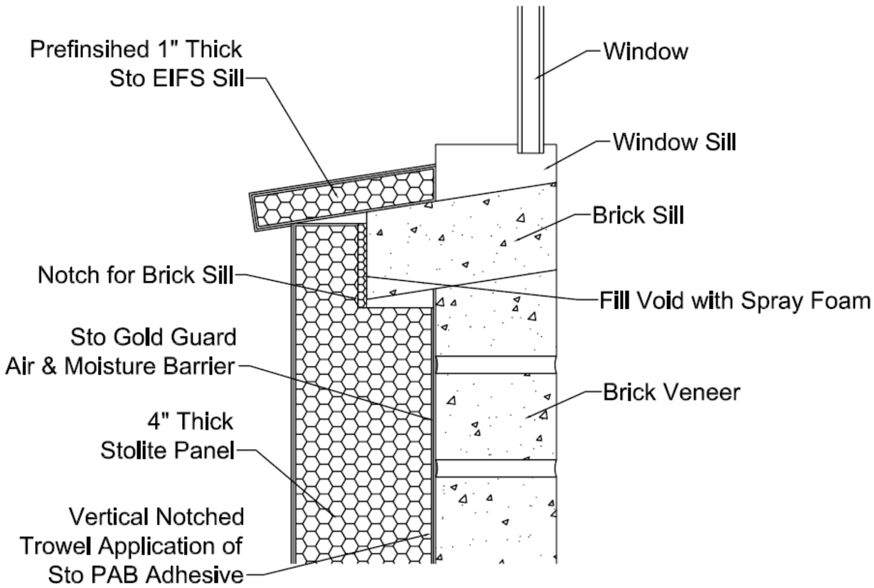
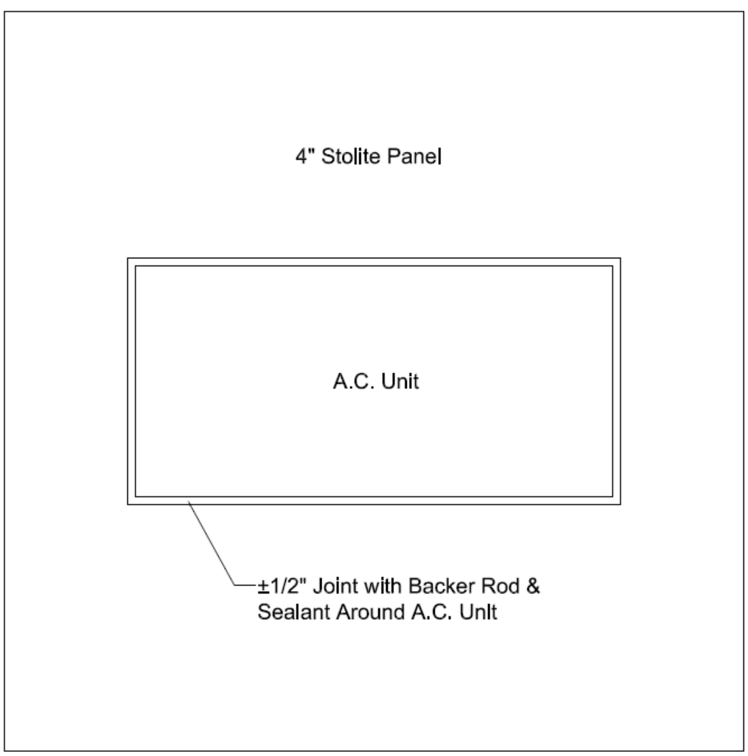


Figure A-6. Panel with cut-out for heat pump



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