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Evaluating an Exterior Insulation and Finish System for Deep Energy Retrofits

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Advanced Residential Integrated Energy Solutions Collaborative

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Evaluating an Exterior Insulation and Finish System for Deep Energy Retrofits

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Definitions

ARIES	Advanced Residential Integrated Energy Solutions Collaborative Building America team
BEopt™	Building Energy Optimization program
CO_2	Carbon dioxide
EIFS	Exterior insulation and finish system
EPS	Expanded polystyrene
HVAC	Heating, ventilation, and air conditioning
NYSERDA	New York State Energy Research and Development Authority
XPS	Extruded polystyrene

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Executive Summary

The expression *deep energy retrofit* lacks precision but broadly suggests a program of existing building improvement that has as one its goals a dramatic improvement in the level of energy efficiency while providing a healthier living environment and improving durability and safety. Adding insulation to exterior walls is often a key piece of a deep energy retrofit. However, this measure is often cost prohibitive and there are formidable challenges to altering the thermal envelope of existing, older structures. This report provides a case study of a deep energy retrofit using a site-applied exterior insulation and finish system (EIFS). Prefabricated EIFS panels are also discussed as a potential wall insulation retrofit solution.

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:

1. Adhesive
2. Foam insulation
3. Base coat
4. Reinforcing mesh embedded in the base coat
5. Top or finish coat.

They can be applied to new or existing buildings that employ wood or masonry construction, and can utilize an insulation thickness of up to 16 in. 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 residential retrofit industry, high cost, and/or lack of suitable distribution channels serving the residential market.

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.

In this project, a home was retrofitted using a site-applied 4-in.-thick EIFS. Site-specific details were developed as required for the residential retrofit application. Site work and the costs of the EIFS were documented.

The case study home was modeled using version 2 of the National Renewable Energy Laboratory-developed Building Energy Optimization (BEopt™) energy and cost analysis software. While a package utilizing the 4-in. 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. This held true for both the Islip, New York (climate zone 4) and Boston (climate zone 5) case studies.

The report discusses the risks, selection criteria, interactions with other building systems, cost, performance, and other aspects of using an EIFS in a deep energy retrofit. EIFSs do not require

special site safety precautions beyond general construction site precautions. Moisture design is important. Trapping moisture between two vapor/air barriers is a risk of 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. Face-sealed approaches that rely on exposed sealants do not provide acceptable rain control or durability and are very risky. Generally, fire codes permit EIFSs for most building types and conditions.

The costs for the case study project were about \$15.50/ft^2 of net wall area (not including windows and door openings) for a 4-in.-thick EIFS, including the water resistive barrier and a standard finish coat. Costs for other insulation thicknesses mainly vary with material costs, because the labor does not change significantly. Extrapolated costs for 2-in. and 6-in. thicknesses are \$15 and \$16, respectively. BEopt modeling indicates that 4-in. thickness results in lower annualized energy-related costs compared to 2-in. and 6-in. thicknesses for a sample retrofit in climate zones 4 and 5. The 4-in. 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.

The case study 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 compared to the pre-retrofit leakage rate of 15 ACH50.

Prefabricated EIFS panels are another potential retrofit approach that will be explored in a future case study. The possible 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 \$7–\$9/ft^2 (net panel area). If proficient applicators can install the water resistive barrier and panels for under \$6/ft^2, then off-site panelization becomes a viable alternative to site-applied systems. Another case study using an off-site panelized EIFS is in progress.

1 Introduction

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. Greater 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 in., 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 a case study project and modeling, one approach for exterior wall insulation retrofits that holds promise for lowering retrofit costs for certain building types: exterior insulation and finish systems.

Exterior insulation and finish systems (EIFSs) are 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 reducing costs and 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 in. thick was cost optimized because above that thickness, additional costs for cladding attachment were incurred. Depending on climate zone, insulation thicknesses of 4–8 in. were found to be cost neutral compared to replacing cladding only (without insulation).

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

Building Science Corporation reports 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. This served as a cost target for the EIFS case study.

1.1 Research Questions

This research addressed the following questions:

1. What is the cost to perform a deep energy retrofit on exterior walls using an EIFS, and what is the relative cost effectiveness of various EIFS thicknesses in selected climate zones?
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?

By answering these questions, this report attempts to bring attention to EIFSs' potential application for residential deep energy retrofits, provide independent data on costs and potential performance targets, and provide guidance to practitioners.

1.2 Relevance to Building America Goals

The overall goal of the U.S. Department of Energy's Building America program is to "reduce home energy use by up to 50% (compared to 2009 energy codes for new homes and pre-retrofit energy use for existing homes)" (Building America Research for the American Home, 2013). As described above, increasing exterior wall insulation levels is critical to achieving deep energy reductions. Finding lower cost approaches for this will be important in gaining market penetration.

2 Background

EIFSs are common in commercial new construction and retrofits.[1] Such products typically consist of five layers installed over the top of a weather resistive barrier:

1. Adhesive
2. Foam insulation
3. Reinforcing plaster or base coat
4. Reinforcing mesh embedded in the base coat
5. Top or finish coat.

They can be applied to new or existing buildings that employ wood or masonry construction, and can utilize an insulation thickness of up to 16 in. 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, 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 most 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 temporary fastening purposes, and a prefinished EIFS surface. Other materials required for this system include a water resistive barrier (either liquid applied or house wrap) over the building sheathing and sealant between panels.

The insulation material most commonly used is EPS, which has a low cost per R-value compared to other rigid board insulations. Unlike XPS, it 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.

[1] For example, StoTherm Classic (http://www.sto.com/evo/web/sto/32331_EN-Products-Products_ystems.htm) has been used worldwide for 40 years.

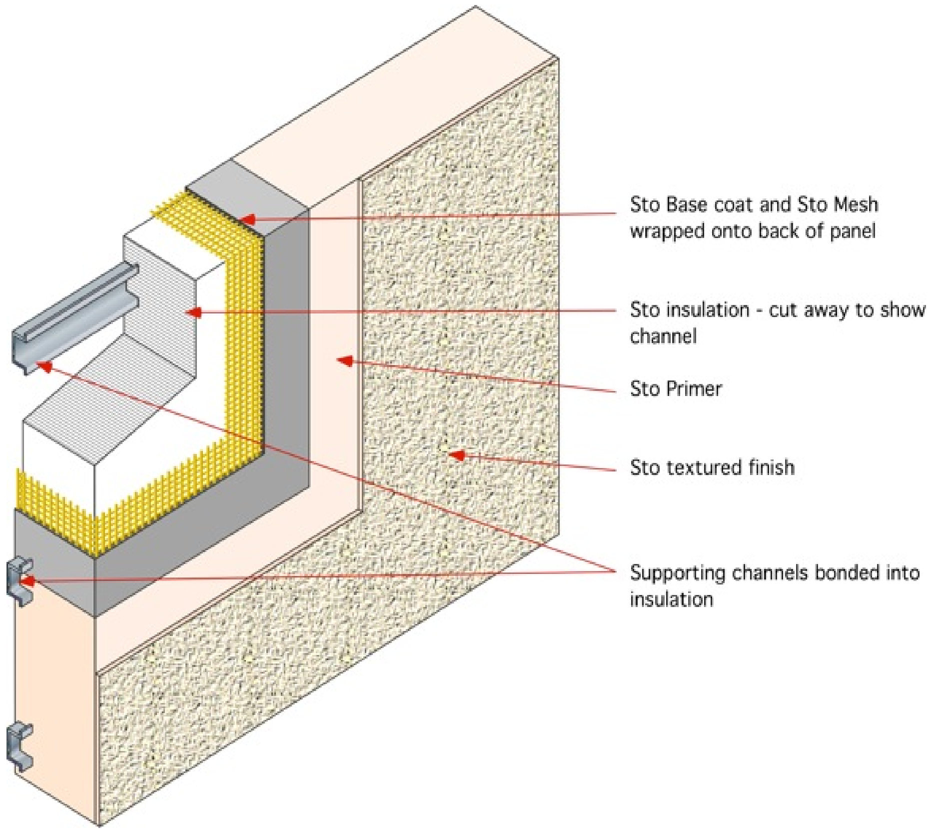

Figure 1. Typical lightweight EIFS wall panel

(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.

Figure 2. Field-applied EIFS showing yellow water resistive barrier, white EPS insulation with yellow reinforcing mesh, and gray basecoat in foreground

In the western United States, stucco is the dominant residential exterior finish. The two most common stucco systems are the traditional three-coat system and the one-coat system. One-coat stucco is typically about a ½-in. thick base and finish layer and may be applied over a 1-in.-thick EPS insulation board. Three-coat stucco is typically ⅞-in. thick (Rapport, Davis, & Brozyna, 2012), including scratch, base, and finish layers. EIFSs typically range in thickness from 1 in. to 4 in., but can be as much as 16 in. thick.

It merits noting that when EIFS became popular in the United States in the 1980s, there were a significant number of serious failures related to rain penetration. Early EIFSs used a face-sealed approach that required perfect installation and no deterioration and had no provision for drainage. This became a problem, especially because the system usually contained moisture-sensitive materials such as gypsum board, oriented strand board, and other wood products. Drained EIFSs include a provision for drainage behind the foam insulation and can be successfully used as an exterior cladding system in most situations (Lstiburek, 2007).

3 Field Study

3.1 Approach

One single-family detached home was retrofitted using a site-applied EIFS. Site-specific details were developed as required for the residential retrofit application. The EIFS thickness was 4 in. The 2-in. × 4-in. 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 to assess the impact of the EIFS on infiltration.

3.2 Case Study Site

The case study site is 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 3.

Table 1. Case Study Home Characteristics

Feature	
Home Type	Single-family detached
Conditioned Floor Area	2,200 ft^2
Foundation	Full unconditioned basement
Structure	2-in. × 4-in. wood frame
Exterior	Vinyl siding—retrofit to 4-in. EIFS
Height	Two stories above grade

Figure 3. Front and rear elevations of the pre-retrofit home

3.3 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 Appendix illustrates the major construction details used to apply the EIFS.

Figure 4 to Figure 12 illustrate the steps of the application process.

Figure 4. After scaffolding is set up a bottom track is attached to the base of the sheathing to accept the bottom of the EIFS.

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 5. A liquid water resistive coating is brushed onto the sheathing; a layer of reinforcing mesh is embedded into the coating at the sheathing joints.

Overhangs at eaves were removed and added back on over rigid insulation to match the 4-in. EIFS thickness. At the gable ends, the roof deck was extended where necessary to match the 4-in. EIFS depth. A metal drip edge was added to direct water away from the rake.

Figure 6. After the coating is complete, more reinforcing mesh affixed around the newly installed windows; it will be used to wrap the edges of the insulation.

The reinforcing mesh at the windows will be wrapped around the edges of the EPS panels, fully protecting them at all exposed surfaces. 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 7. Sections of EPS insulation, 4 in. thick and measuring 2 ft × 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.

Smoothing the joints between EPS foam panels is essential to getting an even finish coat that avoids telegraphing joint lines.

Figure 8. EPS panels are placed around the new windows; an additional 1-in. thick by 4-in. wide layer of EPS is used to form window trim. Other applied shapes can be used to create architectural forms as desired.

Figure 9. The gray basecoat is troweled on over an embedded layer of reinforcing mesh.

The reinforcing mesh provides a durable surface. Additional layers of mesh can be added to increase impact resistance.

Figure 10. 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 11. The finish coat is mixed and applied with trowels.

Figure 12. The finished system

Labor hours were logged for each major step in the process. Table 2 shows the labor breakdown.

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	28.0
Water Barrier*	Brush on liquid-applied coating with embedded mesh reinforcement at sheathing joints	40.0
EPS Board	Adhere 2-ft × 4-ft × 4-in. 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	53.0
Finish Coat*	Trowel on 2-layer finish coat (single layer finish coats are also an option and would take approximately one half the time)	53.5
Total		**278.0**

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

Out of 19 nonholiday days during the EIFS application process from December 14, 2012 to January 10, 2013, 8 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 (not including fenestration) was 1,680 ft^2. Gross square feet per hour were 7.6 and net square feet per hour were 6.

If this system were panelized off site, site labor would be reduced. The 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.

4 Modeling

The case study home was modeled using version 2 of the National Renewable Energy Laboratory-developed Building Energy Optimization (BEopt™) energy and cost analysis software. BEopt cases were run with EIFS thicknesses of 2 in., 4 in., and 6 in. plus a reference case of vinyl siding. 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. It was assumed that the vinyl siding was due for replacement (30 years old). The EIFS cases were compared to replacement with midrange vinyl siding at $4/ft^2 and to high-end vinyl siding at $7/ft^2 (materials and labor). These vinyl siding costs were obtained from the contractor based on local costs.

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 (as indicated in the tables below) of the retrofit are the initial retrofit costs, plus the future replacement costs, plus the costs of operation (energy) averaged over the analysis period.

For the purposes of this modeling exercise the retrofit was assumed to include only the EIFS walls, ceiling insulation, and air sealing because these were the three items deemed “cost-effective” in the BEopt analysis. Cost effectiveness of an energy efficiency measure is defined as having a lower annualized energy-related cost compared to not implementing the measure.

The major modeled characteristics of the house, including capital costs of the initial retrofit measures, are described in Table 3. 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.

Table 3. Modeled House 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-in. 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	
Air Conditioning	10 SEER	13 SEER at wear out	

Measure	Pre-Retrofit	Post-Retrofit	Capital Cost at Time of EIFS Retrofit
Ducts	R-6 in attic and basement	No change	
Lighting	Benchmark	No change	
Water Heating	Gas standard	No change	

BEopt annual energy and utility bill savings are shown in Figure 13. Annualized utility bill savings are $1,028; source energy savings are 141.9 MMBtu/year. Carbon dioxide (CO_2) emission reductions are 8.6 metric tons/year.

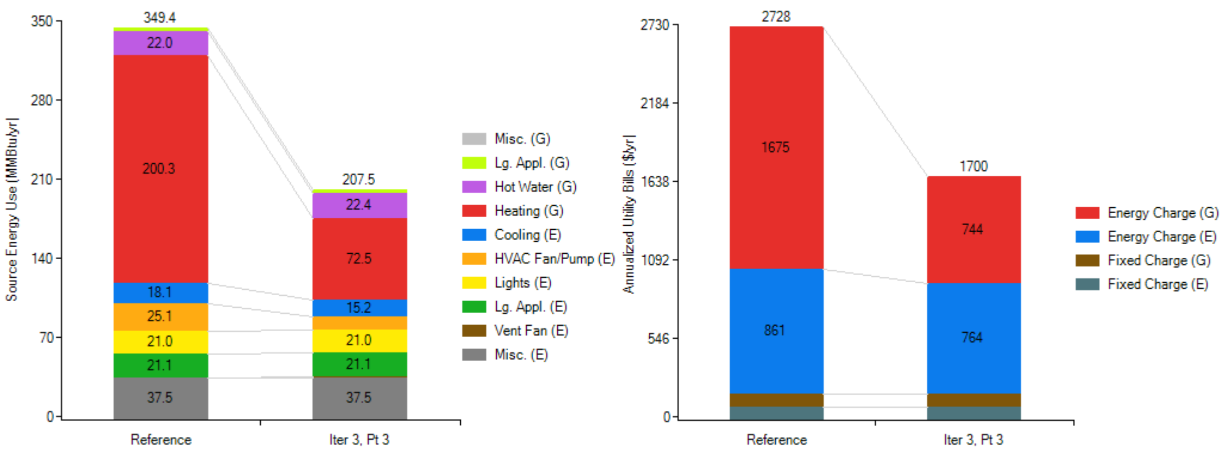

Figure 13. BEopt modeled source energy savings and utility bill savings— Islip, New York; climate zone 4

BEopt optimization curves were generated for two scenarios considering EIFS retrofits with the other enclosure measures listed in Table 4. The optimization was run with two reference cases: midpriced vinyl siding (Figure 14) and high-end vinyl siding (Figure 15), both 30 years old (end of lifetime). BEopt runs multiple cases with various combinations of energy measures considered, over the 30-year analysis period. It then plots the annualized energy-related cost of each case against the percent source energy saved 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 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.

In the analysis with the midrange vinyl siding reference case (Figure 14), the bottom point of the optimization curve includes 4-in. 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 15. Other modeling assumptions are provided in Table 5. Vinyl siding costs are based on local prices obtained from the contractor. EIFS costs are based on actual project costs for 4-in. thickness and manufacturer estimates for other thicknesses.

Table 4. Optimization Options

Measure Considered	Capital Cost	Selected
Mid-Range Vinyl Siding	$9,673	Reference A
High-End Vinyl Siding	$16,928	Reference B
2-in. Thick EIFS	$31,510	No
4-in. Thick EIFS	$32,719	Yes
6-in. 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

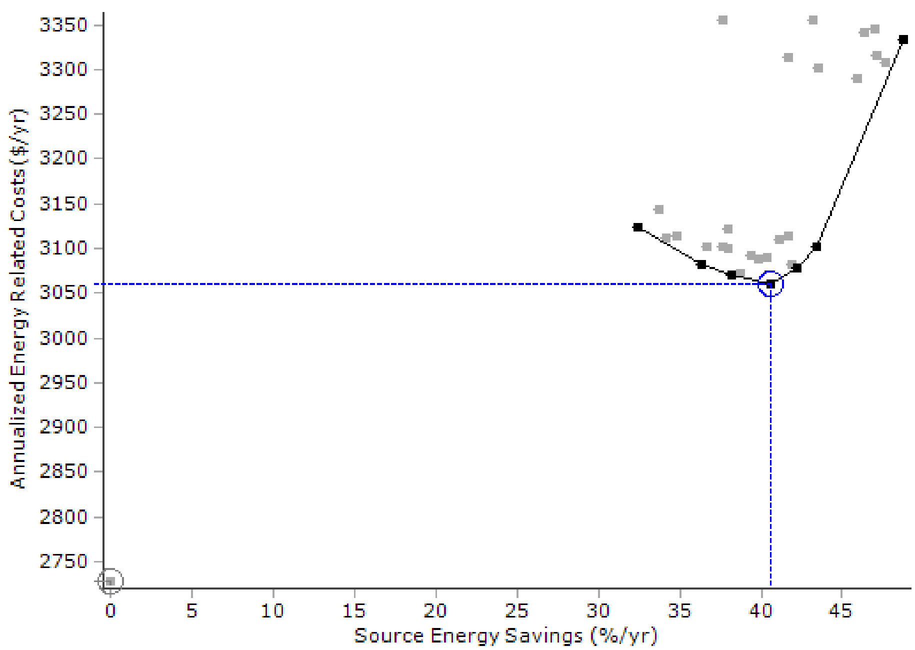

Figure 14. BEopt optimization curve with midrange vinyl siding reference (Islip, New York)

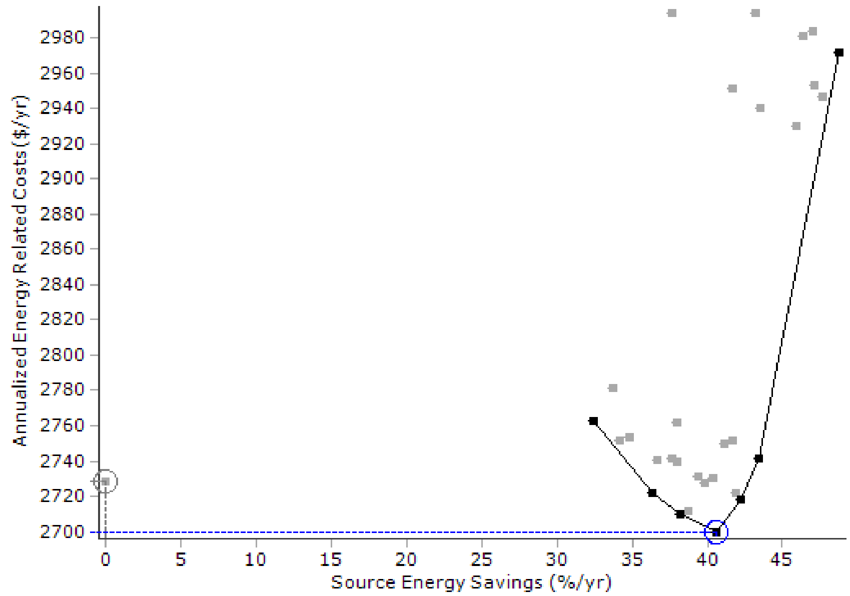

Figure 15. BEopt optimization curve with high-end vinyl siding reference (Islip, New York)

Table 5. 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

Modeling was repeated for Boston, located in the U.S. Department of Energy climate zone 5. The reference home and costs were the same as those used for the Islip location. BEopt annual energy and utility bill savings are shown in Figure 16. Annualized utility bill savings are $1,265; source energy savings are 174.4 MMBtu/year. CO_2 emissions reductions are 10.6 metric tons/year.

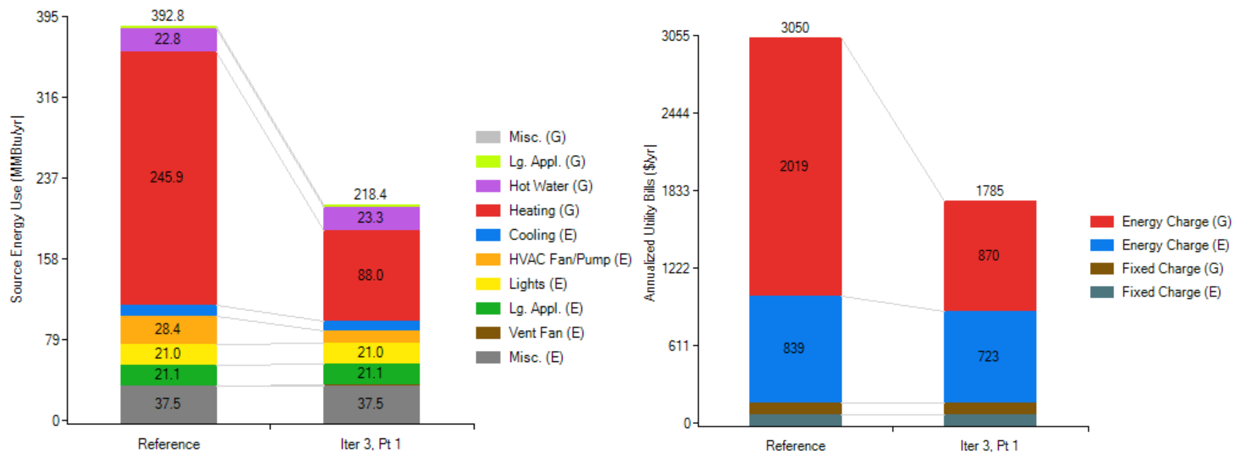

Figure 16. BEopt modeled source energy savings and utility bill savings (Boston)

Figure 17 and Figure 18 show the optimization results for Boston. The same options were selected by BEopt (Table 4). Again, the 4-in. EIFS is the optimal retrofit of the options analyzed in terms of annualized energy-related costs. The optimal retrofit is $95 higher (annualized energy costs) than replacing the siding with midrange vinyl alone (Figure 17). Compared to replacement with high-end vinyl, the EIFS package has a $265 lower annualized energy cost (Figure 18).

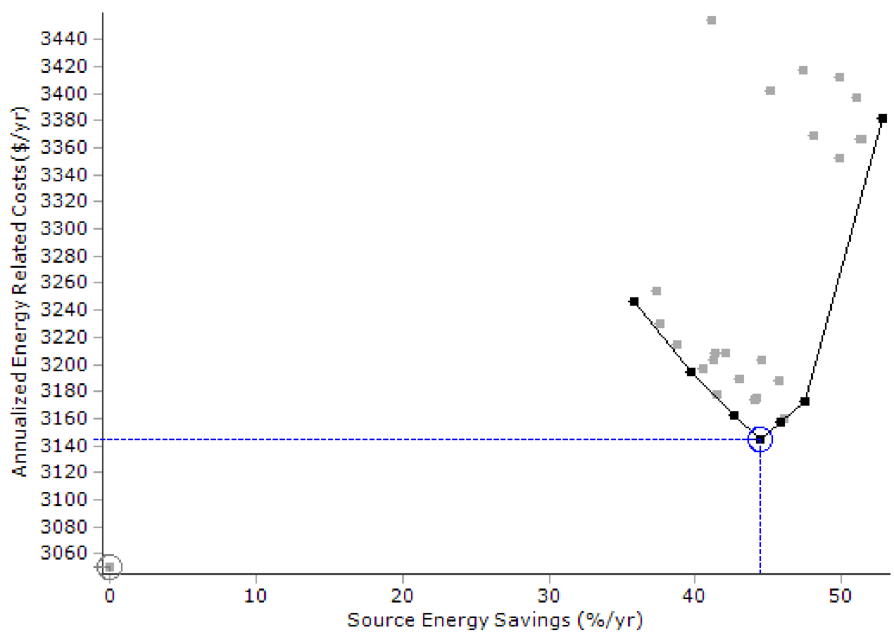

Figure 17. BEopt optimization curve with midrange vinyl siding reference (Boston)

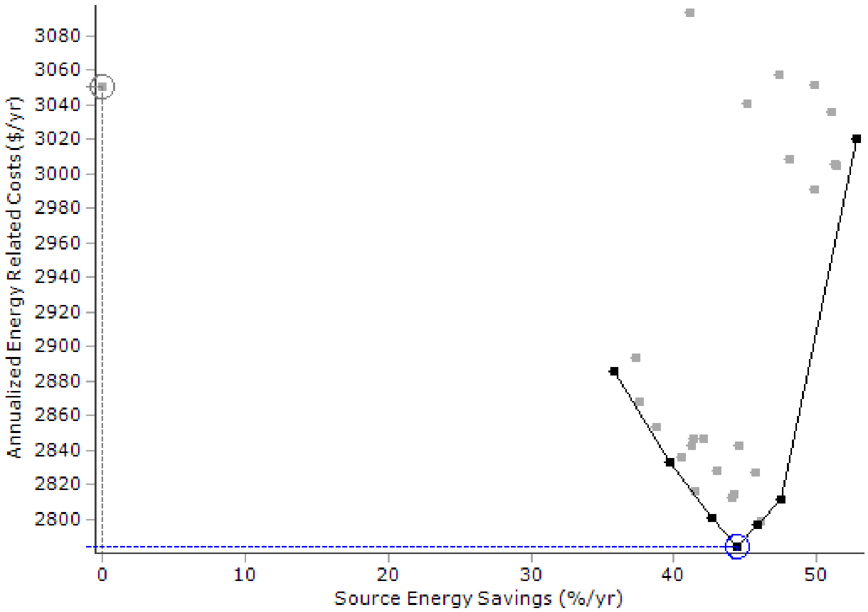

Figure 18. BEopt optimization curve with high-end vinyl siding reference (Boston)

5 Discussion

Before proceeding with the proper installation of an EIFS, it is valuable to understand the cost and performance considerations. The following sections explore the risks, selection criteria, interactions with other building systems, cost, performance, and other aspects of using an EIFS in a deep energy retrofit.

5.1 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 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.

5.2 Installation 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 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 discussed above, 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.

5.3 Code and Regulatory Issues

In most jurisdictions fire codes permit EIFSs for most building types and conditions. 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 as 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).

5.4 Trade Resources

Although EIFSs are not new, they may be new to the local residential construction industry and the 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.

5.5 Maintenance

EIFSs require periodic (approximately every 5 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 projects, 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.

5.6 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. The EIFS cladding is a durable exterior finish that will replace older cladding of unknown condition. Maintenance, as discussed above, is important to ensure durability.

5.7 Occupant Comfort, Health, and Safety

The overall effect of adding exterior wall insulation is to improve comfort conditions for building occupants, versus a 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.

5.8 System Interactions—Enclosure

Retrofitting an EIFS has implications for new or existing windows, doors, and other exterior wall penetrations. The overall wall thickness will increase by 2 in. or more. EIFSs can accommodate either an "innie" (window located at original wall surface as illustrated in the Appendix) 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. Aesthetics also play a role; innies will create recessed windows from the outside, outies will create deep window pockets on the interior.

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

5.9 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 and will result in heating and cooling load reductions. This may result in the need for smaller capacity heating and cooling equipment, reduced ductwork, and 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 if HVAC system controls are not altered to compensate.

5.10 Application Alternatives

When considering an EIFS retrofit, a number of options are available related to waterproofing, finishes, thickness, and fabrication:

5.10.1 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 and also 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 is called *ghosting*. Over time, the parts 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.

5.10.2 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.

5.10.3 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 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 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 for areas 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 5 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.
- Also, as discussed in Section 5.4, fabricators and applicators capable of delivering the panelized system may be hard to find.

5.10.4 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 1 in. to as much as 16 in. is possible.

5.11 Cost

One of the primary motivations of this project is to evaluate the cost effectiveness 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 case study site were tabulated and are shown in Table 6. This cost includes the water resistive barrier, 4-in. insulation, and base and finish coats.

Table 6. Case Study 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
Cost per Square Foot	$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.[2]

For off-site fabricated panels, a number of sources were contacted for estimates. The lowest costs for panel components was found to be \$7–\$8/ft^2 for 2-in. thick panels with an additional \$0.40/ft^2 for each additional inch of thickness beyond 2 in. Adhesives and caulk are estimated at \$0.50/ft^2. Site labor is highly variable depending on the building configuration and experience of the contractor.

5.12 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 described above 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, equipment efficiency, retrofit characteristics, and the cost of the alternative cladding system. High fuel prices (e.g., oil heat rather than gas), a cold climate, poorly insulated existing walls, leaky existing walls, and low retrofit costs (relatively simple geometry) will improve the cost effectiveness of an EIFS retrofit.

[2] Cost extrapolation based on input from Sto Corp. and http://www.ecoevaluator.com/building/energy-efficiency/insulation-application-and-cost.html.

6 Conclusions

This research addressed three primary research questions, each of which is repeated below along with the respective results.

1. What is the cost of a deep energy exterior wall retrofit using an EIFS, and what is the relative cost effectiveness of various EIFS thicknesses in selected climate zones?

The costs for the case study project were about $15.50/ft^2 of net wall area for a 4-in.-thick EIFS, including the water resistive barrier and a standard finish coat. Costs for other insulation thicknesses mainly vary with material costs, because the labor does not change significantly. Extrapolated costs for 2-in. and 6-in. thicknesses are $15 and $16, respectively. BEopt modeling indicates that 4-in. thickness results in lower annualized energy-related costs compared to 2-in. and 6-in. thicknesses for a sample retrofit in climate zones 4 and 5. The 4-in. 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.

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?

The Gibbs Road case study project achieved a blower door test result of 2 ACH50. No in-process diagnostic blower door tests were conducted and no remedial air sealing was needed to obtain this result. 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 compared to pre-retrofit rate of 15 ACH50).

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 $7–$9/ft^2 (net panel area). If proficient applicators can install the water resistive barrier and panels for under $6/ft^2 then off-site panelization becomes a viable alternative to site-applied systems. Another case study using an off-site panelized EIFS is in progress.

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Appendix: Construction Details

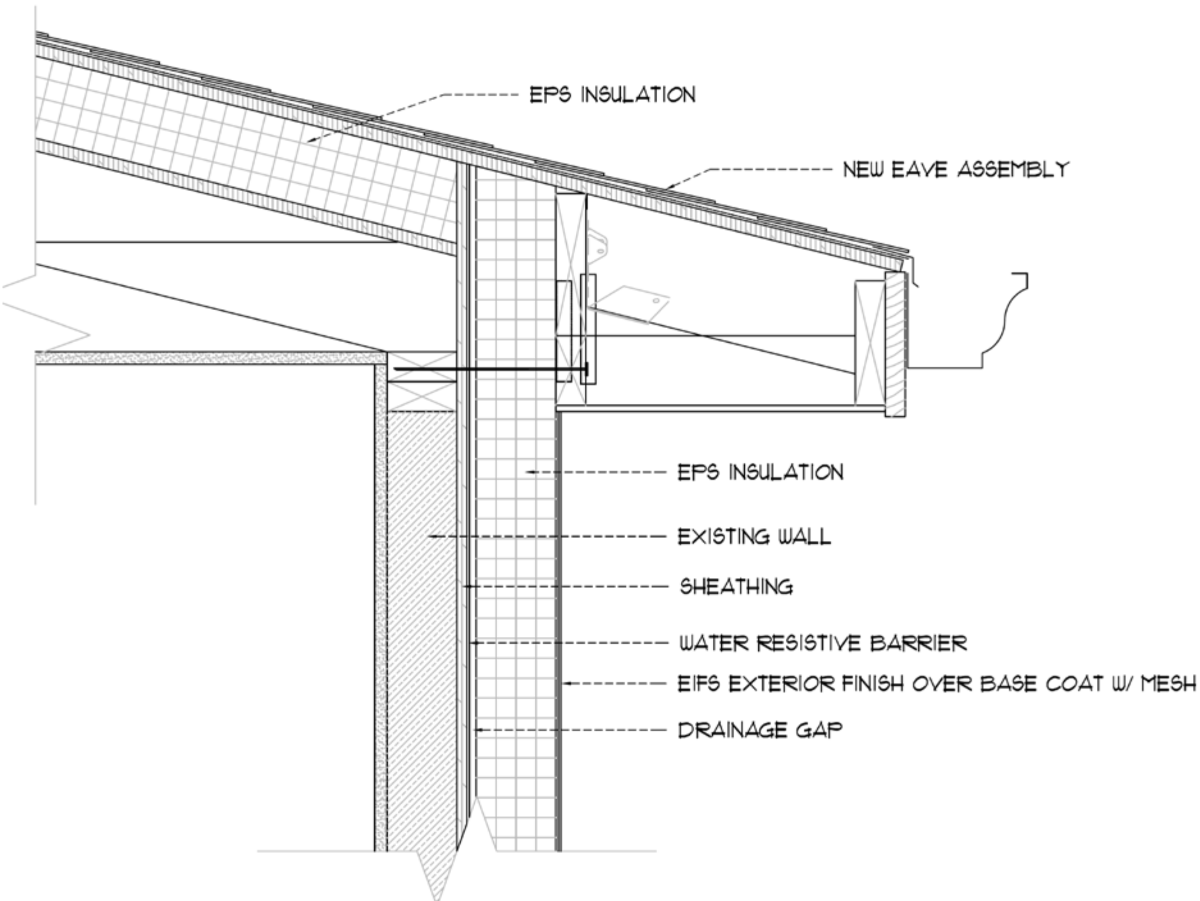

Figure 19. Eave detail. The existing eave was removed.

(adapted from Fusion Architects)

To construct this eave detail, the existing eave overhang was removed by cutting off the rafter tails (often referred to as a *chainsaw retrofit*). Rigid foam insulation was added to the roof along with new roof sheathing and shingles that extend beyond to join with a new bolted-on eave assembly. The new eave assembly may be added after the EIFS is installed, or if (as is likely) the roof is installed first, then rigid insulation that matches the EIFS thickness can be installed behind the eave and the EIFS subsequently mated to it. The result is a continuous blanket of 4 in. (in this case) rigid insulation over the walls and roof, virtually eliminating thermal bridges.

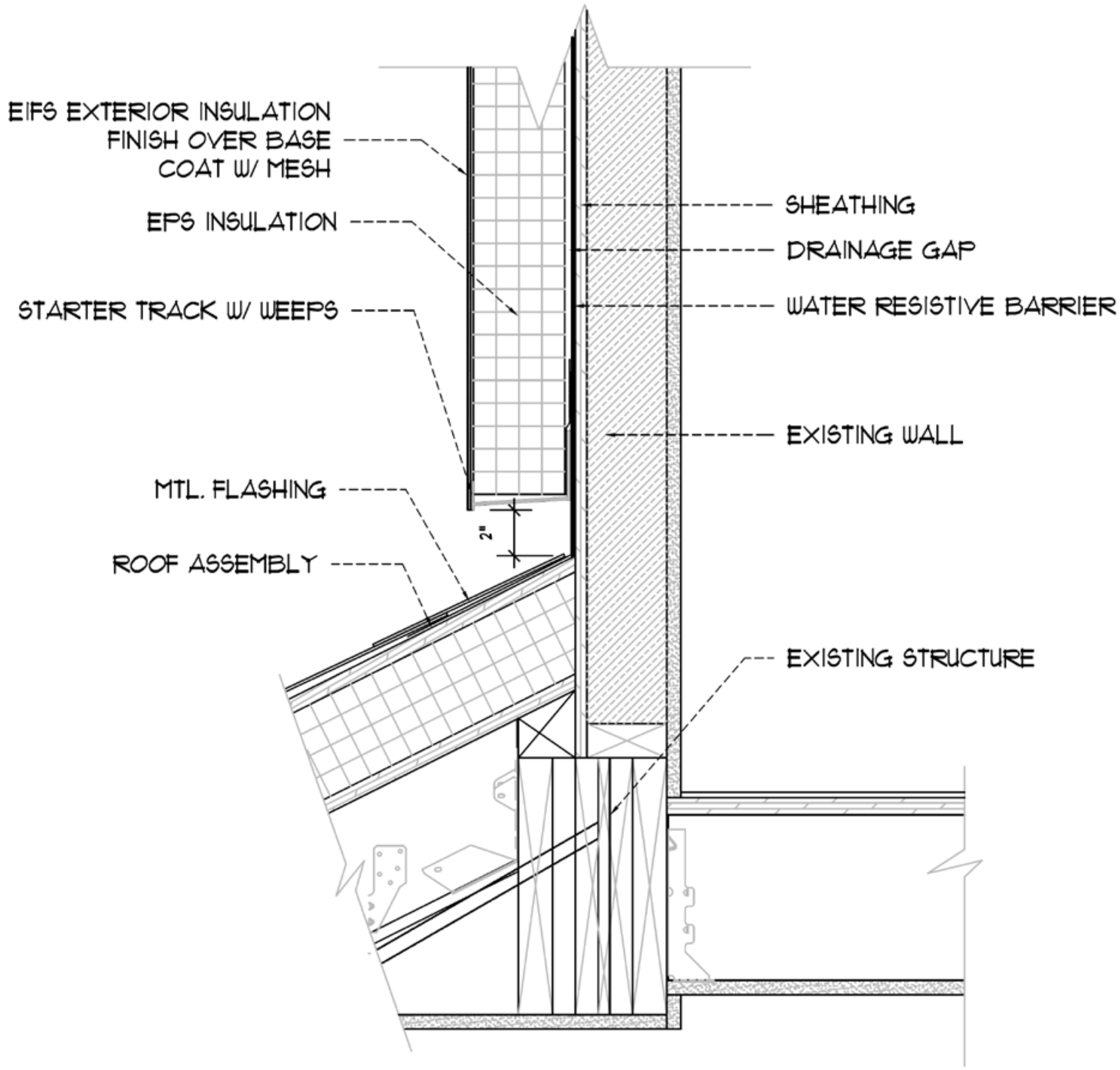

Figure 20. Detail at porch roof. A 2-in. gap is left between at the bottom of the upper wall EIFS.

(adapted from Fusion Architects)

The wall at a roof-wall intersection is treated similar to at the foundation with a starter track and gap (minimum 2 in.) to provide drainage and facilitate future roof replacement without damaging the EIFS.

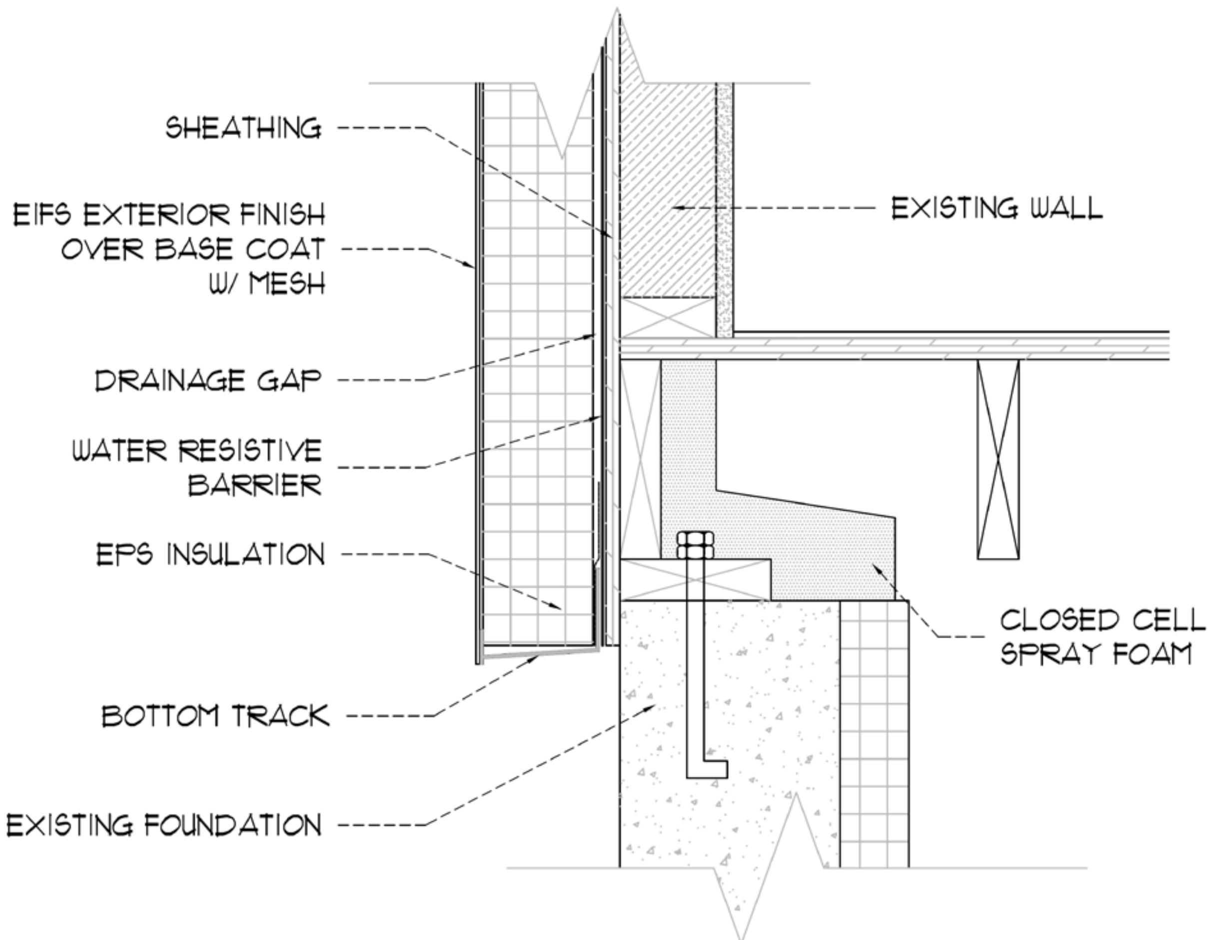

Figure 21. Detail at foundation

(adapted from Fusion Architects)

The EIFS should be kept at least 8 in. above grade to prevent dirt from clogging the bottom track weep holes. This detail includes interior rigid foam basement wall insulation and closed cell spray foam at the rim joist for a continuous thermal enclosure.

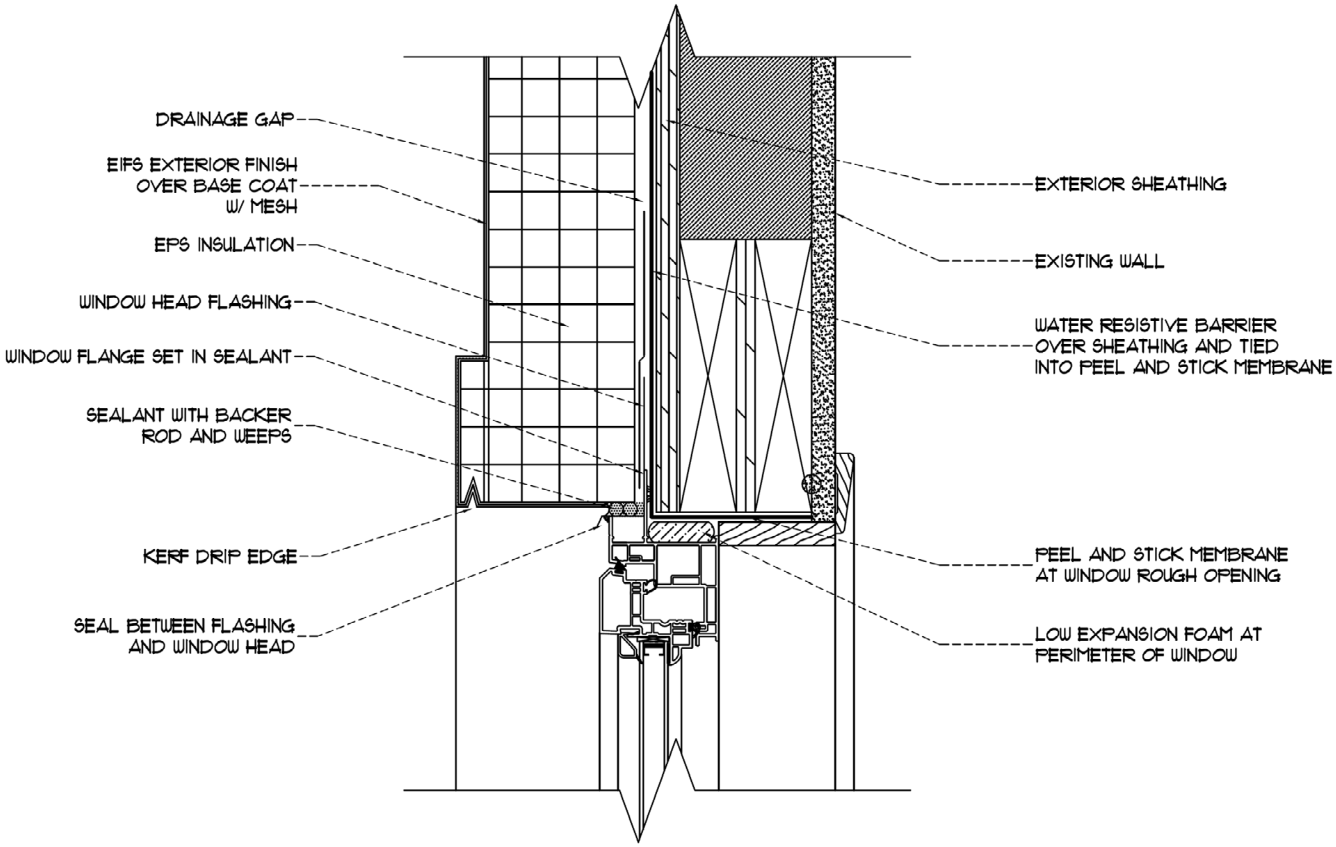

Figure 22. Detail at window head. The water resistive barrier ties into the window flashing. (figure adapted from Fusion Architects)

The window head detail includes a 1-in. × 4-in. casing detail built into the EIFS for architectural detail. It includes a kerf cut so water drips off the EIFS rather than running under the head towards the window. In this case study the windows were replaced in their original location at the sheathing surface of the existing wall. Window flashing was tied into the EIFS water resistive barrier. In an EIFS retrofit where windows are not replaced, care would need to be taken to ensure that window openings were adequately flashed and tied into the new water barrier.

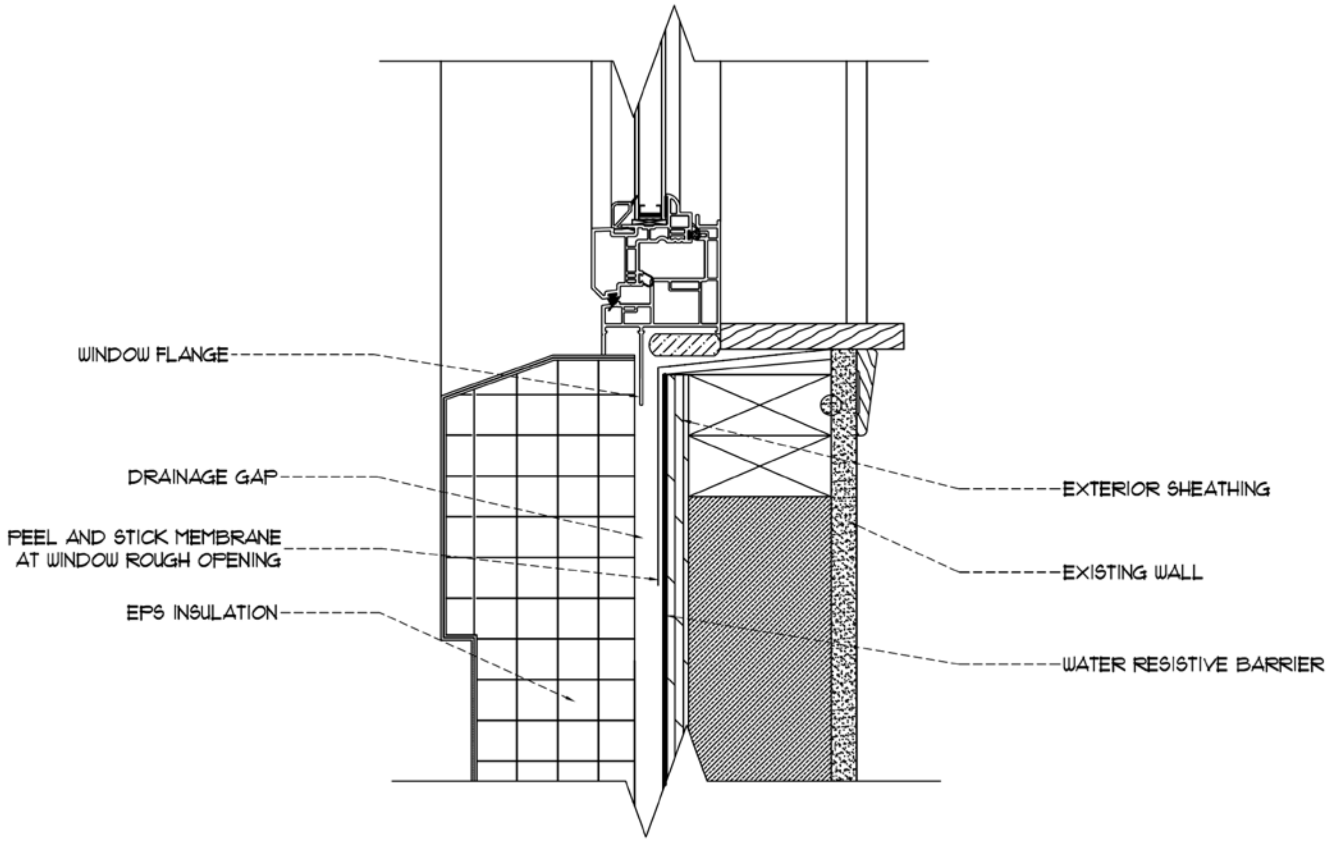

Figure 23. Detail at window sill

(adapted from Fusion Architects)

Window sill flashing must tie into the new EIFS water resistive barrier, making sure that the drainage gap remains open from the window down to the bottom of the wall. The EIFS foam was built out to form a trim detail along the bottom of the window. The sill is sloped so water, including water that drips down from the kerf cut at the window head, flows to the outside.

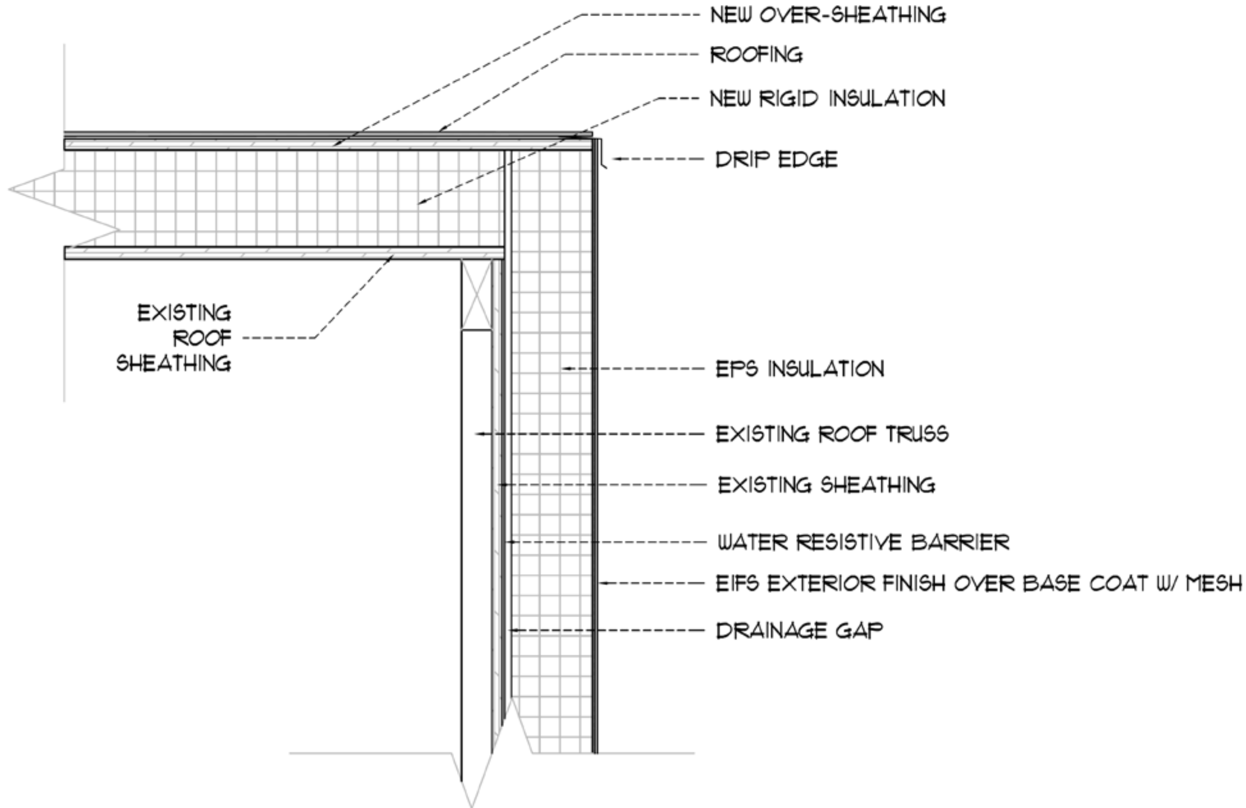

Figure 24. Detail at rake

The new roof sheathing extends out beyond the existing wall to overhang the new EIFS. A metal drip edge protects the top of the EIFS from water intrusion.

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