

Evaluation of Two CEDA Weatherization Pilot Implementations of an Exterior Insulation and Over- Clad Retrofit Strategy for Residential Masonry Buildings in Chicago

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Ken Neuhauser

Abstract:

This project examines the implementation of an exterior insulation and over-clad strategy for brick masonry buildings in Chicago. The strategy was implemented at a free-standing two story two-family dwelling and a larger free-standing multifamily building. The test homes selected for this research represent predominant housing types for the Chicago area. High heating energy use typical in these buildings threaten housing affordability. Uninsulated mass masonry wall assemblies also have a strongly detrimental impact on comfort. Significant changes to the performance of masonry wall assemblies is generally beyond the reach of typical weatherization (W ∞) program resources. The Community and Economic Development Association of Cook County, Inc. (CEDA) has secured a Sustainable Energy Resources for Consumers (SERC) innovation grant sponsored by the United States Department of Energy (DOE). This grant provides CEDA the opportunity to pursue a pilot implementation of innovative approaches to retrofit in masonry wall enclosures. The exterior insulation and over-clad strategy implemented through this project was designed to allow implementation by contractors active in CEDA weatherization programs and using materials and methods familiar to these contractors. The retrofit measures are evaluated in terms of feasibility, cost and performance. Through observations of the strategies implemented, the research described in this report identifies measures critical to performance as well as conditions for wider adoption. The research also identifies common factors that must be considered in determining whether the exterior insulation and over-clad strategy is appropriate for the building.

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Ken Neuhauser
Building Science Corporation

August 2013

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Unless otherwise noted, all tables were created by BSC.

Definitions

ACH50	Building air changes per hour induced by a relative pressure difference of 50 Pascals between the building and ambient conditions
BSC	Building Science Corporation
CEDA	Community and Economic Development Association of Cook County, Incorporated
CEDA Wx	CEDA Weatherization, a division of CEDA
cfm50	Airflow, usually through an enclosure or assembly induced by a relative pressure difference of 50 Pascals
CMU	Concrete masonry unit
DOE	U.S. Department of Energy
EIFS	Exterior insulation and finish system
ft ²	Square foot, square feet
IHWAP	Illinois Home Weatherization Assistance Program
OSB	Oriented strand board
PVC	polyvinyl chloride
R-value	Insulation value of walls and roofs
SERC	Sustainable Energy Resources for Consumers, an innovation grant program of the U.S. Department of Energy
U factor	Insulation value of windows
Wx	Weatherization
XPS	Extruded polystyrene

Executive Summary

This project examines the implementation of an exterior insulation and over-clad strategy for brick masonry buildings in Chicago. The strategy was implemented at a free-standing, two-story, two-family dwelling and a larger free-standing multifamily building. The test homes selected for this research represent predominant housing types for the Chicago area. High heating energy use typical in these buildings threatens housing affordability. Uninsulated mass masonry wall assemblies also have a strongly detrimental impact on comfort. It will be necessary to significantly change the performance of the wall if these masonry buildings are to be elevated to a level of performance on par with current standards.

Significant changes to the performance of masonry wall assemblies is generally beyond the reach of typical weatherization (Wx) program resources. Community and Economic Development Association of Cook County, Incorporated (CEDA) has secured a Sustainable Energy Resources for Consumers (SERC) innovation grant sponsored by the U.S. Department of Energy (DOE). This grant provides CEDA the opportunity to pursue a pilot implementation of innovative approaches to retrofit in masonry wall enclosures. This research project evaluates the implementation of an exterior insulation and over-cladding approach at two masonry buildings representing predominant types within the Chicago-area housing stock. The retrofit measures are evaluated in terms of feasibility, cost, and performance.

The exterior insulation and over-clad strategy was designed to allow implementation by contractors active in CEDA Wx programs and using materials and methods familiar to these contractors.

The research identifies:

- Conditions under which exterior insulation and over-clad of masonry walls is recommended
- Significant implementation challenges to exterior insulation and over-clad of masonry walls
- Levels of airflow control that can be achieved with the strategy
- Risks inherent in the approach that must be addressed
- Measures and practices critical to achieving performance in exterior insulation and over-clad of masonry walls
- Successful strategies to integrate windows into masonry wall exterior insulation and over-cladding systems.

Through observations of the strategies implemented, the research described in this report identifies measures critical to performance as well as conditions for wider adoption. The research also identifies common factors that must be considered in determining whether the exterior insulation and over-clad strategy is appropriate for the building.

1 Problem Statement

The predominant construction types for residential structures—single-family detached as well as multifamily—in Chicago involve load-bearing masonry walls. Methods to insulate these wall assemblies are typically beyond the reach of Wx programs. Yet, the need for improved thermal performance in these masonry buildings is clear. Residential buildings in the Chicago area exhibit appreciably higher heating energy use than other types of construction and other cold climate regions of the country (AGA 2010). Energy costs are an increasing burden on household incomes. Uninsulated mass masonry wall assemblies with poor performing glazing also have a strongly detrimental impact on thermal comfort. It will be necessary to significantly change the performance of the wall thermal enclosure if these masonry buildings are to be elevated to a level of performance on par with minimum current code standards.

Adding insulation to the walls of such masonry buildings in cold, and particularly cold and wet, climates may cause performance and durability problems in some cases. The problems and solutions are outlined by practitioners such as Maurenbrecher et al. (1998), Gonçalves (2003), and Straube and Schumacher (2002, 2004).

Examples of concerns associated with interior insulation of mass masonry walls include freeze-thaw damage—due to reduced outward heat flow—and the decay of wood structural framing members (typically floor joists) that are embedded in mass assemblies—due to increased equilibrium moisture contents. The masonry freeze-thaw issue has been examined by (among others) Mensinga et al. (2010) and Straube et al. (2012). The embedded floor joist decay issue has been studied by some practitioners (Dumont et al. 2005; Morelli 2010; Ueno 2012), but many issues remain unresolved.

In addition to the risks associated with interior insulation of mass masonry, this strategy has limitations to performance in factors such as the common occurrence of integrated floor or wall assemblies representing thermal bridges. The amount of insulation that can be accommodated to the interior of a mass masonry wall without reconfiguring the interior space is typically limited to the depth of interior framing or strapping cavities and the performance of insulation materials that can be loose blown into these cavities.

When a building is occupied, the application of interior insulation strategies can be very disruptive to residents. Working around resident schedules and belongings also tends to significantly complicate the implementation.

Adding insulation to the exteriors of existing buildings has been demonstrated to be an effective means to overcome these limitations and provide higher effective R-values for building wall assemblies. The benefits of this approach extend beyond just added thermal resistance; benefits of increased building durability and airtightness are often also realized (Ueno 2010).

The underlying concept of insulating the exterior of existing masonry walls has a variety of advantages for durability and air barrier continuity (Hutcheon 1964; Lstiburek 2007). Furthermore, exterior insulation retrofit can often achieve a greater amount of thermal resistance than is typically feasible with interior insulation retrofit. The practice should be simple; however, several problems stand in the way of widespread implementation. For example, manufacturers of cladding systems and exterior insulation materials often limit thicknesses to 1½ in. with their

warranties; the cladding attachment is therefore an issue. This problem has been tackled by various researchers and practitioners (Straube and Smegal 2009; Pettit 2009; Joyce 2009; Ueno 2010; Baker 2012). Demonstrations by members of our research team have shown that up to 8 in. of exterior insulation over the exteriors of masonry and frame buildings is practical (Lstiburek 2009).

The lack of widespread recognition of attachment methods by manufacturers has resulted in obstacles for building official and building code acceptance. Additionally, the construction industry has not demonstrated familiarity with details for water management and integration of window systems, door systems, decks, balconies, and roof-wall intersections in assemblies with thick exterior insulation. Baker (2012) proposed an engineering basis and support for the installation of thick layers of exterior insulation on existing masonry and frame walls. His report also demonstrates water management details necessary to integrate windows, doors, decks, balconies, and roofs.

Long-term solutions to the energy cost burden and comfort problems of existing masonry construction buildings will require measures to improve the performance of the masonry wall assemblies. Widespread adoption of one possible solution, exterior insulation of masonry walls, will require demonstration projects that prove the feasibility of the techniques and evaluate challenges. Through the SERC innovation grant, CEDA has the opportunity to demonstrate and study such measures. Through a Building America partnership, Building Science Corporation (BSC) has partnered with CEDA to provide technical guidance for—and evaluation of—the retrofit measures implementation. In providing technical guidance toward water management details and cladding attachment, BSC drew on previous and concurrent research into exterior insulation retrofits.

2 Project Context

2.1 Chicago Masonry Buildings

Masonry buildings are the dominant residential building type in Chicago. While this may be expected for large older multifamily buildings, it is also true of smaller residential buildings in Chicago. According to Cook County Assessment Department data, 57% of one-unit housing stock and 58% of two- to four-unit housing stock in Cook County is of masonry construction.¹

Compilation of utility data shows Illinois has the second-highest average gas consumption per residential customer for all the United States (AGA 2010). Only residential gas customers in Alaska use more, on average, than residential gas customers in Illinois (see Figure 1). Homes within the CEDA service territory are using even more on average than the rest of the state, surpassing the residential customer average for Alaska and using nearly twice the gas per household as other heating climate areas such as Minnesota.

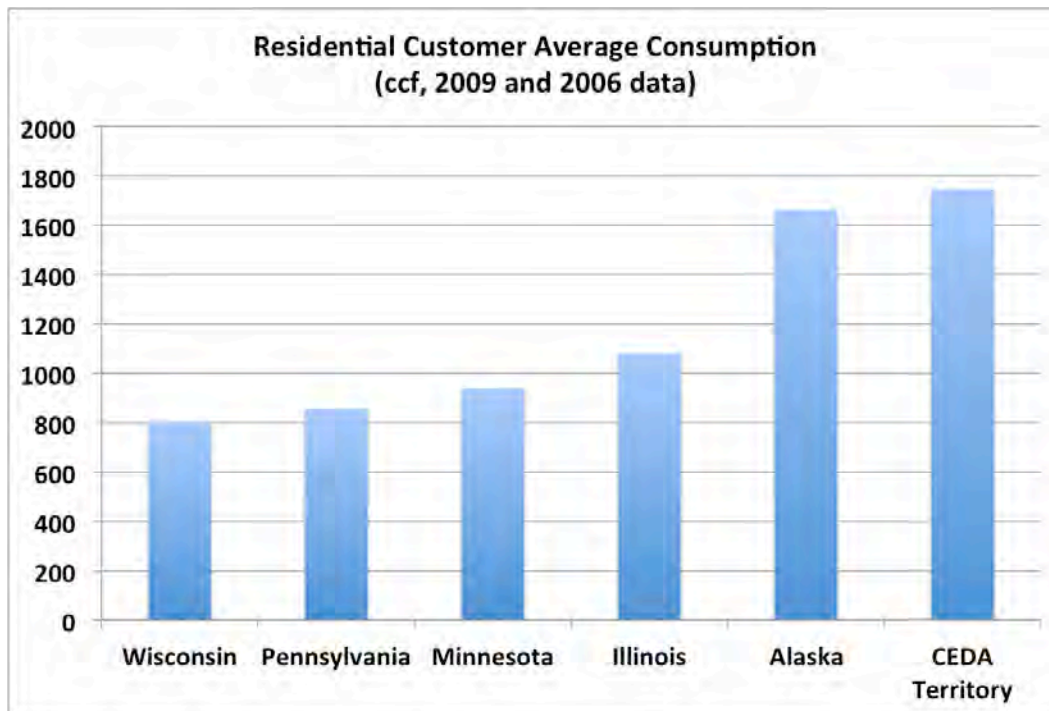


Figure 1. Average gas consumption per residential customer for several cold climate states and the CEDA territory

2.2 CEDA Weatherization

The Multifamily portion of the Illinois Home Weatherization Assistance Program (IHWAP) is for building owners who provide housing to income-eligible residents in Chicago and suburban Cook County. The program is at no cost to the building owner, if 66% or more of the tenants are income eligible.

¹ Percentages reported are based on 2010 data.

The CEDA Wx program serves income-eligible clients and includes households residing in multifamily buildings, in Cook County, Illinois. A multifamily building qualifies for services if at least two thirds of the households in a multifamily building are income eligible.

CEDA Wx is one of more than 30 community action agencies that participate in IHWAP. The Illinois Department of Commerce and Economic Opportunity administers the program; its Office of Energy Assistance monitors all agencies in the IHWAP network.

The services that CEDA Wx provides are structured around a comprehensive energy audit performed by a CEDA Wx assessor. The audit leads to development of a work order that may comprise measures in the following categories:²

- Retrofit measures: insulation, compact fluorescent lamps, refrigerator replacement, low-flow shower heads and faucet aerators, heating system replacement, window and door replacement
- Air sealing measures
- Health and safety measures (limited to \$600 per unit): handrails, fire extinguishers, gutters, downspouts, and decommissioning of unvented space heaters
- Incidental repair measure (limited to \$500 per unit).

DOE Wx program funding requires that the entire building or house receive a savings-to-investment ratio of 1 or greater before it can be weatherized.³ Software tools are used to estimate the savings from various measures. Costs per work item are sent to bid by approved contractors. The state-level administration of IHWAP sets a limit of \$5,200 to the expenditure for each eligible unit. Approved contractors participating in the CEDA Wx programs implement the work scope. Upon completion of the work, CEDA Wx assessors conduct inspection of the work.

CEDA weatherizes all types of single-family and multifamily structures. In typical years, CEDA Wx has weatherized 3,000–4,000 housing units. Units in multifamily buildings typically account for 10%–30% of the total number of housing units served. With funding made available through the American Recovery and Reinvestment Act, the budgeted volume of units has increased to a total of 7,500 units in 2010, 11,000 units in 2011, and 9,000 units in 2012.

Because the regular program limits are the same for each stand-alone single-family house as for a unit in a multifamily building, the program resources relative to enclosure area and per building tends to be significantly higher for multifamily buildings participating in the programs. This has allowed for measures such as replacing windows with high performance windows to be implemented through the Wx program in multifamily buildings. However, the Wx program has not been able to implement measures to address the masonry-bearing walls.

The high proportion of masonry buildings within the CEDA service territory creates a persistent challenge for CEDA Wx programs. An analysis of the programs found that energy use reductions achieved by Wx activity in homes of masonry construction are typically one third less than what is achieved in wood-framed homes. It is certainly conceivable that this reflects the

² Note that the list of allowable measures in the program has changed slightly since the period of research.

³ Typically, the value of savings is taken as the present value of recurring savings for a period of time at a standard discount rate. The present value of savings is then compared to the initial cost or investment of the measure.

thermal performance of masonry wall assemblies and the lack of opportunity for improvement at levels of investment commensurate with typical Wx programs. The furring cavity between the brick wall and the interior finish does not provide adequate space for effective insulation. The program has not pursued measures based on interior wall build-out for insulation due to anticipated costs and complications. Neither has insulation and recladding at the exterior been incorporated into available measures. Such strategies have been generally regarded as too unfamiliar to the contractor base and as potentially representing fire safety concerns.

In 2011, CEDA was awarded special grant funding through the SERC program, an innovation grant program of DOE. This grant allowed CEDA to apply resources beyond regular Wx program allocations at a limited number of selected projects. The grant allowed the budget for a single-family unit to increase by \$9,600 and for multifamily unit by \$6,400.

The SERC innovation grant has provided CEDA the opportunity to pursue limited implementation of various strategies to address building performance weaknesses that have heretofore been out of reach of the Wx programs. One of the innovations that CEDA opted to pursue with this funding is exterior insulation and cladding of masonry walls.

2.3 BSC-CEDA Research Collaboration

In 2010 CEDA and BSC gathered CEDA Wx personnel, management, and selected consultants to envision a path toward significantly increasing performance of homes treated through CEDA programs and, in particular, masonry buildings. These meetings identified major packages of measures to be researched through prototype and/or pilot implementations. Taken together, the major packages describe a comprehensive high performance retrofit. The first package that the collaboration evaluated through a series of implementations was an advanced Wx approach for the roof of 1½-story brick bungalow homes (see Neuhauser 2012).

The SERC grant provided a potential opportunity for the BSC-CEDA collaboration to evaluate another major package for masonry buildings: insulating and over-cladding of masonry walls. BSC and CEDA began the preliminary work of developing schematic details for the over-clad assembly and evaluating a number of potential building candidates.

After BSC and CEDA began this preliminary work, two factors emerged that resulted in disruptions to the collaborative effort. On the one hand, management changes within the CEDA organization resulted in uncertain support for the project. On the other hand, the wider national political climate created some uncertainty as to whether BSC would be able to support its involvement in the project. As a result, funding and implementation of the exterior insulation and over-cladding project were uncertain during significant portions of the originally projected project timeline. This affected BSC's ability to participate in the project. In fact, BSC's participation was essentially suspended for a period from prior to contractor bidding until just prior to the start of construction. As a result, critical windows of opportunity to provide guidance to contractors and to obtain pre-retrofit performance data were missed. The availability of CEDA resources was also constrained during the project. This hampered collection of certain post-retrofit performance data.

3 Relevance to Building America's Goals

The energy performance goal of the DOE Building America program is to reduce home energy use by 30%–50% compared to 2009 energy codes for new homes and pre-retrofit energy use for existing homes. For CEDA such reductions in existing homes are imperative to maintaining housing affordability and quality of life for CEDA's constituents. It is clear that uninsulated masonry walls are a significant source of heat loss in any heating-dominated climate. Long-term housing affordability and comfort will require retrofits of these assemblies.

The use of exterior insulation on wall assemblies is an effective means to provide additional thermal resistance to enclosure assemblies. The exterior insulation approach is particularly well suited to retrofit projects, as it minimizes disruption to the interior and does not detract from usable floor area. Exterior insulation retrofit strategies present the possibility to far exceed current code levels of performance for new exterior walls.

The specific target of the measures implemented through this research and the dominant target of CEDA Wx programs generally is to reduce energy costs and improve comfort in a heating-dominated climate. Demonstrating an effective masonry retrofit strategy will support wider adoption of an approach with great potential. This potential is remarkable both in terms of the level of benefits to individual treated buildings and residents of these buildings as well as in terms of the number of buildings to which the strategy is applicable. The measures demonstrated and evaluated in this research task are complementary to measures demonstrated and evaluated through Neuhauser (2012). The measures demonstrated and evaluated in that research task as well as those evaluated in the current research task constitute components to comprehensive masonry building retrofit.

4 Cost Effectiveness

4.1 Factors Affecting Cost Effectiveness

There exist at least three somewhat inherent challenges to assessing the cost effectiveness of the type of exterior insulation retrofit evaluated in this report. First, the cost of adding layers of insulation to the exterior of the building is extremely front loaded. That is, the major costs associated with adding thick layers of insulation are incurred with the first layer of insulation added. Second, the front-loaded costs of insulation are inextricably linked to nonenergy benefits. And third, conditions of access to the building represent a significant cost determinant for the approach and would cause the cost to vary widely between buildings.

Most of the cost of an exterior insulation retrofit is represented in the attachment system and cladding needed with the first layer of exterior insulation. Typically, methods of insulating assemblies face diminishing returns as thermal resistance is increased. Cost effectiveness—in terms of incremental energy savings relative to incremental cost—of additional insulation would depend upon the incremental cost decreasing more than the energy savings diminishing.⁴ In the case of exterior insulation and over-clad of masonry structures, subsequent layers or thicknesses of insulation added to the system entail a much lower cost than the initial level of thermal resistance represented by the base system. Because of the high relative cost of the initial level of insulation and the diminishing costs for subsequent layers, cost effectiveness relative to energy savings is likely to improve as insulation is added *after* the initial layer of insulation.

The measures necessary to allow installation of the first layer of insulation in the exterior insulation and over-clad approach are also responsible for important nonenergy benefits of the approach (see Section 4.2). Therefore, it would be logical to assign a portion of the costs for this layer to nonenergy benefits, leaving less than the full cost of this layer assigned to the energy benefits. Such apportioning of costs among benefits has a profound effect on perceptions and measures of cost effectiveness relative to energy savings or other benefits.

Both the working area at the base of a building and the height of the building will have a significant impact on the ultimate cost to provide exterior insulation and over-clad. In terms of height, the inflection point in cost is above two stories in height. Occupational safety regulations permit access by ladder for work on structures up to two stories in height. Above this height, staging or a lift mechanism would be required, thus significantly increasing the cost of the job and the resulting unit cost for the measure. The contractors involved in this research project indicate that a mechanical lift operating from the ground is the least costly and most flexible means to perform exterior building enclosure work above two stories. Use of such a lift, however, would require a relatively large area of clear and level ground adjacent to the building. Such access is not unheard of in urban environments, but also, certainly cannot be expected as a typical condition. When there is not sufficient space for operation of a mechanical lift on the ground adjacent to the building, pipe staging or, where the building can support it, swing staging would be required. These represent significant additional cost and labor time burdens relative to a mechanical lift. Even below two stories, working access is a significant factor in the unit cost

⁴ Cost effectiveness expressed this way is sometimes an overly simplistic metric. There are other rationales, such as an energy cost risk management and energy performance differential over the life of the measure that may be used in identifying appropriate levels of insulation.

of the measure, as space between adjacent buildings may not be sufficient to allow the use of ladders. In fact, the development pattern for most of the territory that is served by CEDA Wx has narrow spacing along the sides between adjacent one- and two-family buildings. The contractors performing work in this research project generally regarded the ground-level access as more important than building height as a factor in overall project cost.

4.2 Tradeoffs and Other Benefits

Improved durability, water management, and comfort are nonenergy benefits expected from the implementation of the measures outlined in this report. Other potential nonenergy benefits include reduced maintenance and improved aesthetics. This research task will not attempt to quantify the value of these nonenergy benefits, although it does seek to document them.

Using exterior insulation has many additional benefits other than simply increased thermal resistance. In masonry building assemblies, the potential for freeze-thaw is practically eliminated, since this approach not only keeps the masonry warmer, but also addresses the exterior rainwater absorption into the masonry (which is the leading moisture source related to freeze-thaw damage to buildings). Another benefit is the increased condensation resistance that this strategy provides for cold climate buildings.

In addition to keeping the structure to the inside of the thermal control layer and thereby avoiding the risks of freeze-thaw damage associated with placing the masonry structure to the outside of the thermal control layer, the strategy employed in this research provides a platform for superior water management. The approach evaluated in this research uses a continuous water control layer that is applied over the face of the brick masonry and integrated with new or existing flashings to direct water out to a drainage cavity or over the surface of the cladding. The use of furring strips for cladding attachment over thick exterior insulation also creates a drainage cavity that allows water penetrating through the new cladding layer to quickly drain out of the system. The fact that the furring strips are an intrinsic component of this system provides a significant added benefit to the long-term durability of these wall assemblies.

A fundamental benefit of insulating uninsulated masonry walls is thermal comfort improvements resulting from radiant surface temperature effects. The techniques used in this insulation and over-cladding strategy are also expected to result in air leakage reduction. Air leakage reductions would result in energy savings and could also benefit comfort, indoor air quality, and building durability.

The application of an insulation and cladding assembly over an existing masonry wall could also result in reduced maintenance expenses and improved aesthetics. Reduced maintenance expenses would result where the building owner regularly maintained the masonry wall such as by periodically repointing the brick. The owner of one of the buildings that is the subject of this research reports hiring a contractor to perform repointing on a portion of the building every year. Other building owners might be performing little to no maintenance on the masonry and, therefore, would not see savings from reducing maintenance needs.⁵

The improvement in aesthetics is, admittedly, a subjective assessment. Pertinent to the assessment, however, is the condition of the existing masonry over which this insulation and

⁵ The building would certainly benefit in terms of longevity of the masonry. This may not be a concern for all building owners, however.

over-cladding strategy would be applied. The side and rear walls of residential masonry buildings in Chicago are typically found to be of lower quality masonry than the street-facing elevations. Side and rear walls typically have mortar joints that are not struck and brick that is of visibly lesser quality and of inconsistent colors.

4.3 Contrast to Interior Insulation Strategies

In contrast to exterior insulation, insulation to the interior of existing masonry walls does not provide comparable benefits to building durability and water management. Insulation to the interior of the building structure will also make that structure colder (in heating seasons) thereby increasing the potential for condensation in the assembly, freeze-thaw damage to the masonry, and moisture degradation to embedded framing members. While insulation to the interior of masonry walls does not necessarily portend certain disaster regarding these damage functions, risks need to be carefully assessed for each circumstance. Therefore, it is not possible to propose a uniform approach for widespread application.

Interior insulation does not offer the opportunity to improve exterior aesthetics or reduce maintenance requirements for the exterior masonry. On the other hand, it is very common that the street elevation of Chicago masonry buildings exhibit detailing and quality of work that has a definite aesthetic value to the building. Exterior insulation and over-cladding of these street façades would not be desirable.

Relative to what can be achieved with exterior insulation, it is challenging to achieve similar levels of thermal performance with insulation applied to the interior of existing masonry walls. Interior insulation strategies will either reduce usable floor area or be limited by the depth of framing or furring cavities. Even where nominal thermal resistance in the field of the wall is comparable, interior insulation of mass masonry has greater limitations to effective performance due to the common occurrence of thermal bridges such as integrated floor or wall assemblies.

Interior insulation may be readily accommodated in interior renovation activities involving removal or significant replacement of interior finishes along the exterior wall. If significant removal of interior finishes is not planned, interior insulation will typically require appreciable repair to exterior wall finishes. Thus, interior insulation approaches represent significant disruption to the use of the interior. A very significant constraint to interior insulation that will apply to virtually all buildings in active use is that interior insulation strategies are not easily compatible with an occupied retrofit.

5 Research Project Description

This research project leverages targeted grant funding obtained by CEDA to implement a strategy to address the thermal losses and comfort detriment inherent in the masonry bearing wall construction, the predominant wall assembly for residential buildings in the Chicago area. It is understood that addressing these losses and comfort impacts is important to the long-term viability of this housing stock. It is not known, however, whether the retrofit packages demonstrated in these buildings will be able to be delivered through Wx program channels outside of special grant funding.

5.1 Research Questions

The research project evaluates a masonry wall retrofit approach involving exterior insulation and over-cladding. The research project is aimed at answering the following questions pertinent to wider implementation of the approach:

- Under what conditions or for which common building situation is the strategy recommended?
- What are the most significant challenges to implementation?
- What level of airflow control improvement can be expected with the strategy?
- What risks inherent in the strategy must be addressed in the implementation of the strategy?
- What are the recommended practices critical to achieving performance?
- What are successful strategies to integrate windows into a masonry wall insulation and cladding retrofit system?

Answers to these questions will help researchers, developers, contractors, and designers to evaluate the application of these strategies both within the Chicago area as well as elsewhere.

5.2 Technical Approach

The research activities include the following:

- Conduct in-field assessments of prospective retrofit community homes/buildings to identify both unique and common characteristics of building construction.
- Develop schematic details for insulation and over-clad systems and for integration of windows with the system.
- Conduct prework measurement of air leakage and building conditions.
- Review contractor bids and shop drawings, revise assemblies and details as necessary.
- Perform oversight and observation of contractor implementation of measures.
- Conduct postwork air leakage measurement and monitoring of conditions within parts of buildings affected by measures.
- Analyze cost and performance data.

CEDA Wx program assessors and Multifamily Program staff mined the CEDA Wx database of eligible customers to identify likely homes and buildings to participate in the research effort. Criteria used in this initial screening included willingness and interest of the building owner, building height of three or fewer stories, solid masonry bearing wall construction, uninsulated wall assembly, masonry in reasonably good condition without major repointing required, reasonable access to roof-wall intersection, and full eligibility for regular program incentives. Assessors then visited the homes and buildings to document conditions and obtain measurements of pertinent building geometries.

Following preliminary selection of a set of candidate buildings, BSC developed schematic assembly drawings and details for both the general and unique conditions identified. The research team was able to provide oversight of the measure implementation at each of two buildings involved in the research.

Some planned research activities were not carried out due to funding uncertainty and unanticipated resource constraints. In the initial plan for this research, BSC was to review work scopes prepared by CEDA prior to bidding by the implementing contractor. The research partnership had earlier envisioned that BSC would be present during bidding conferences or other meetings with prospective contractors to explain the strategy and answer questions. As discussed in Section 2, BSC participation was suspended during the bid process and up until the start of construction. As a result, BSC did not have an opportunity to review contractor bids or shop drawings (there do not appear to have been any of the latter). BSC did prepare revised details in response to observations made during site visits at the early stage of construction.

Obtaining useful pre-retrofit air leakage measurements of the larger building involved in the study proved infeasible due to the conditions of occupancy and the size of the building. CEDA personnel were able to perform air leakage testing at the smaller of the two buildings involved in the study.

5.3 Subject Buildings

The two buildings selected to participate in this research include a two-story, two-family building and a larger multifamily building containing 80 single-room occupancy units. The larger multifamily building features three occupied floors over a basement that contains some meeting and office spaces associated with the operation of the facility.

5.3.1 Two-Family Building

Although it is a multifamily building, the two-family building represents many characteristics typical of single-family homes. These typical characteristics include the project scale, the spacing between buildings, and a more finely articulated street façade (Figure 2). A very common feature of detached single-family masonry homes that is not represented in this subject building is an intersection between an exterior wall and a roof overhang. Instead the subject building has a low-sloped roof with a parapet at the intersection of the treated wall and roof. This configuration is not uncommon. It required a connection from the wall system, over the parapet to the roof. Subsequent to launching construction on this building, it was found to have another feature apparently common in low-sloped buildings of similar age in the area: a parapet in significant disrepair.

The inclusion of two qualifying dwelling units within the building allowed a larger budget for the enclosure retrofit than would be possible with a single-family home.



Figure 2. Two-family over-clad candidate
(Credit: Scott Sanders, CEDA)

Because of the limited space between buildings, pipe staging (scaffolding) was required for working access to the building. For one side of the building, even the narrow staging used (extending approximately 5 ft from the building) was feasible only because the same owner owned both properties to either side of a small alleyway.

Windows on this building had been replaced with double-glazed, low-e, vinyl-framed windows through a different low-income Wx program prior to CEDA involvement. The available budget for this project did not permit removal and reinstallation of these windows.

Because of the significant aesthetic value of the brickwork at the front of the building, the front section was not included in the insulation and over-clad project. The rear of the building was also excluded because of an attached fire escape. The relocation or reconstruction of this fire escape, as would have been required, was beyond the budget of the project.

5.3.2 Larger Multifamily Building

The larger building included in this project provided the scale representing many urban multifamily buildings. It required staging or lifts such as would be required for buildings more than two stories in height. For this pilot implementation, portions of two sides of the building were designated to receive the insulation and over-clad assembly (Figure 3 and Figure 4). The reasons for designating portions of the wall rather than the entire wall include the constraint of available budget for this work, reasonable access (a portion of the north-facing wall is less than 1 ft from an adjacent building) and preference of the building owner to allow CEDA to implement

an “experimental” exterior treatment to less visible portions of the building. These designated portions of the wall provided ample area to evaluate a large-scale implementation of the exterior insulation and over-cladding strategy.

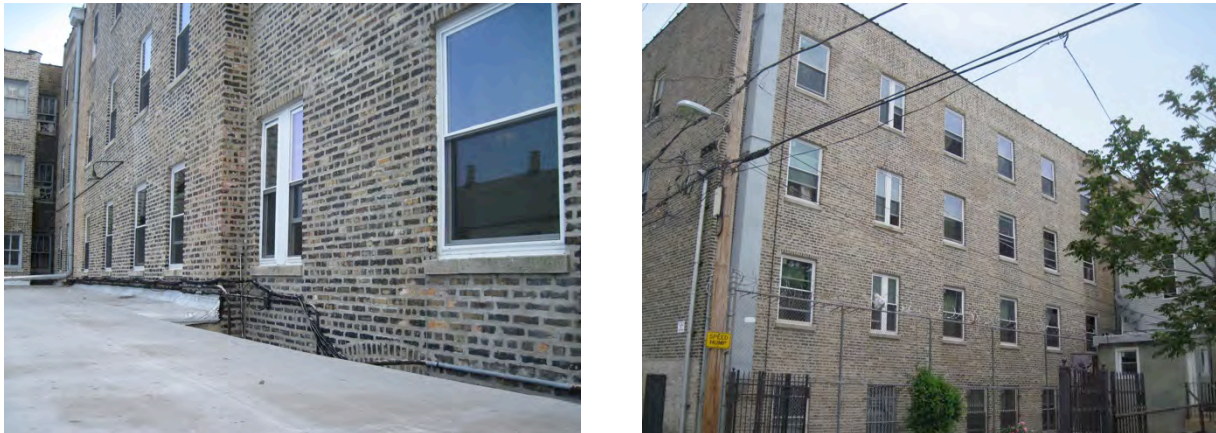


Figure 3. (L) North side of larger multifamily over-clad candidate; (R) south side of larger multifamily over-clad candidate
(Credit: Scott Sanders, CEDA)

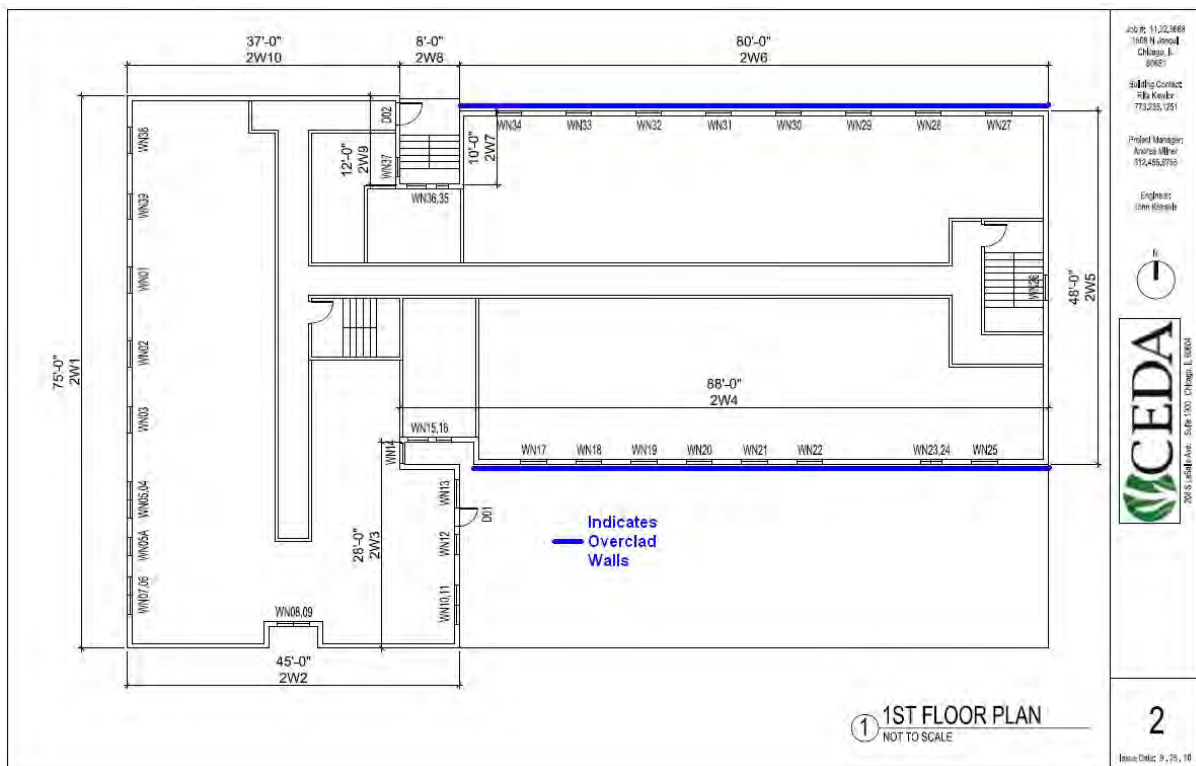


Figure 4. Plan footprint of larger multifamily building showing location of walls receiving the insulation and over-clad assembly
(Credit: CEDA)

Because of the access constraints, work on both designated sides of the building required the use of a suspended staging.

Windows on this building had been recently replaced with high performance vinyl-framed windows through a CEDA Wx program. The windows were designated to remain in place.

5.4 Data Sources

The information used in the evaluation of the measures derives from field observation, interviews with implementing contractors and crews, project documents, performance measurements, and simulation analysis.

5.4.1 Field Observation

Both during early stages of implementation at the larger building and throughout the implementation at the smaller two-family building, CEDA Wx personnel made regular and frequent visits to the job site. CEDA Wx personnel took photos during visits and rapidly conveyed these photos (sometimes before leaving the jobsite) to BSC for review. Upon a joint review of the photos and discussion of job site issues, CEDA Wx and BSC would develop directions to convey to the contractors as well as areas to investigate in subsequent field visits.

BSC personnel visited the project sites with CEDA Wx personnel during the candidate building selection phase as well as during implementation of measures. These visits proved valuable for understanding site conditions and observing apparent challenges.

5.4.2 Interviews with Contractors

Onsite review of the implementations also presented opportunities to gain candid assessments from the contractors and crews. This provided useful insights into challenges encountered. Meetings were also scheduled with contractors after significant completion of the work to provide an opportunity for the contractors to provide feedback and for the research team to ask questions of the contractors. Follow-up telephone and electronic communications with contractors also provided useful information.

5.4.3 Bids and Other Project Documents

Contractor bids provide a basis for determining measure costs. Submittals provided by contractors with each bid indicate specific products included in the materials costs. Work orders prepared by CEDA provide additional information about the cost of measures and scope of work. As change orders were not allowed on this project, the bids of the contractors implementing the work reflect the cost paid for the work.

5.4.4 Performances Measurement

For the smaller building, pre- and post-retrofit air leakage measurements are used to derive a cfm50 measurement for the building. These measurements are then normalized to enclosure area and treated wall area. There are some problems with this methodology for assessing the air leakage reduction attributable to this strategy. First, the air leakage measurement changes also reflect work other than that associated with the insulation and over-cladding measure. Also, because of likely airflow pathways within and between wall assemblies, the results from treating portions of the wall do not necessarily extrapolate to the case of treating all nonstreet elevations of the building.

For the larger building, pre-retrofit air leakage measurements were conducted within individual residential apartments. It was not possible to conduct guarded leakage tests for individual apartments. Given the suspected presence of overriding interunit leakage that obscures changes in leakage through exterior walls, the team did not pursue post-retrofit air leakage testing in this building.

Given the timeframe for the research and that of measures implementation, it was not possible to obtain energy consumption data reflecting heating season conditions after implementation of the measures.

5.4.5 Simulation Analysis

Simulation analysis using BEopt is employed to project the impact of the retrofit measures on heating energy usage. The simulation analysis reflects an idealized case where the whole exterior wall assembly can be treated to the same level of thermal performance. While this results from a limitation of the simulation tool, it also represents a comprehensive retrofit scenario where the exterior insulation and over-cladding treatment is paired with a different but complementary treatment for the street elevation.

6 Over-Clad Retrofit Assembly

Basic parameters of the insulation assembly were identified during initial discussions between the research partners about joint research into insulation and over-cladding. Since the purpose of the research was to evaluate a system that might be applied through CEDA Wx programs the system had to (1) be composed of components that could be installed by contractors working in the Wx programs; (2) be as low cost as practical; (3) not provoke objections from building officials and local code officials relative to fire risk; and (4) accommodate at least a nominal R-20 of exterior insulation.

Exterior insulation and finish systems (EIFS) might seem a logical fit for retrofit insulation of masonry buildings. Indeed, these systems were initially developed for this application. However, the installation of an EIFS would generally require specially trained or franchised contractors. Also, the expanded polystyrene substrate used in EIFS systems available in the United States would surely raise concerns relative to fire risk. Insulated metal panels have been used in high performance retrofits of masonry buildings, but these systems are presumed to represent a cost that could not reasonably be considered to be within the reach of Wx programs. Metal panels or another cladding system installed over mineral fiber insulation might be an option that would satisfy fire safety concerns; however, stand-off brackets or other attachments capable of accommodating the desired amount of insulation are not readily available.

Based on the parameters identified for the retrofit assembly, the research partnership determined that the retrofit assembly would include wood furring fastened to the face of masonry, rigid or semirigid board insulation, strapping, and fiber-cement siding attached to the strapping. The assembly would also include a fully adhered air and water control membrane over the face of the masonry. The basic assembly that forms the basis for the retrofit assemblies evaluated in this research project is consistent with the recommended cladding design for masonry walls identified in previous Building America research (see Baker 2012). An illustration from the technical report for this research is reproduced in Figure 5 below. In this assembly, the wood furring or framing is attached to the masonry with standard exterior-grade masonry fasteners, the strapping is attached to this wood framing with long exterior-grade screws, and the fiber cement is attached with fasteners typically used for fiber cement installation.

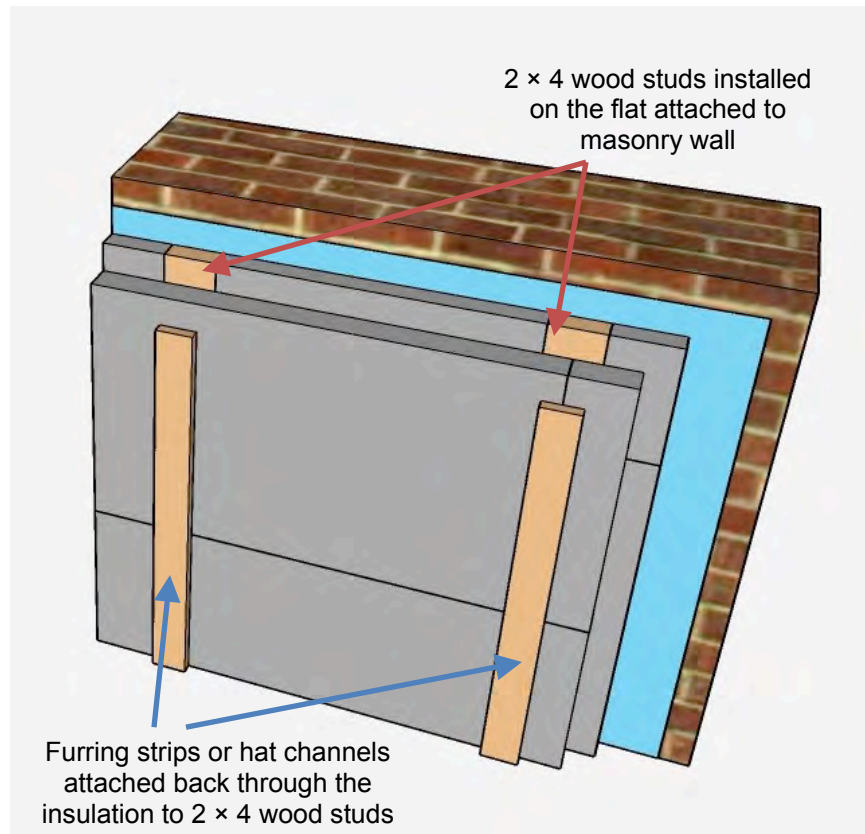


Figure 5. Exterior insulation strategy adopted as the basis for the assembly to be implemented through the research project

BSC prepared schematic drawings of the retrofit wall assembly for preliminary discussions with the City of Chicago Building Department. The research team's preferred approach included foil-faced polyisocyanurate insulation, wood framing against the masonry, and wood strapping for attachment of fiber cement cladding (Figure 6 and Figure 7). This assembly demonstrates robust thermal performance and was also deemed by the research team to provide robust fire resistance due to the material nature of fiber cement siding and the fire resistance rating of the specific insulation material.

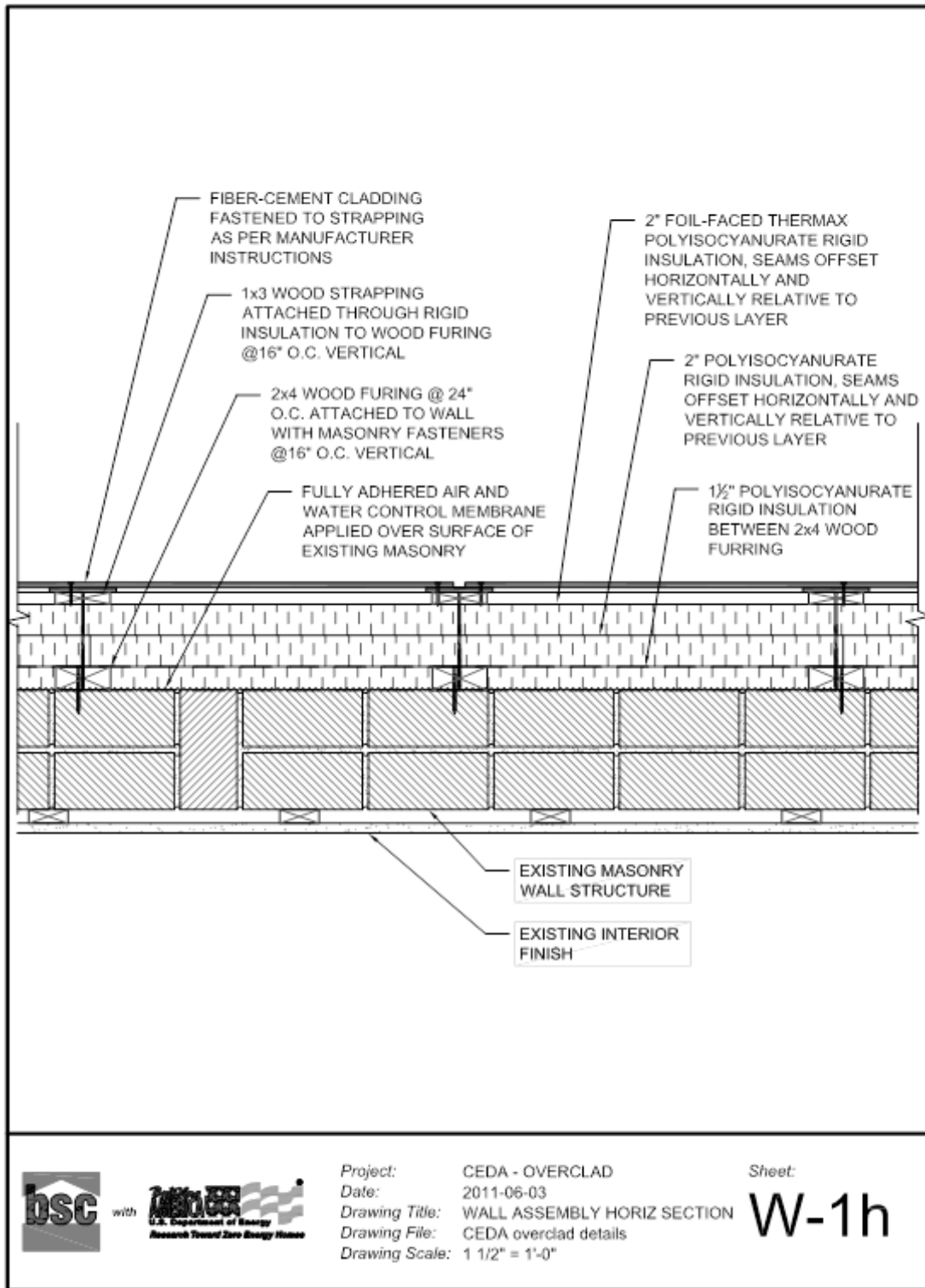


Figure 6. Schematic retrofit assembly, plan view

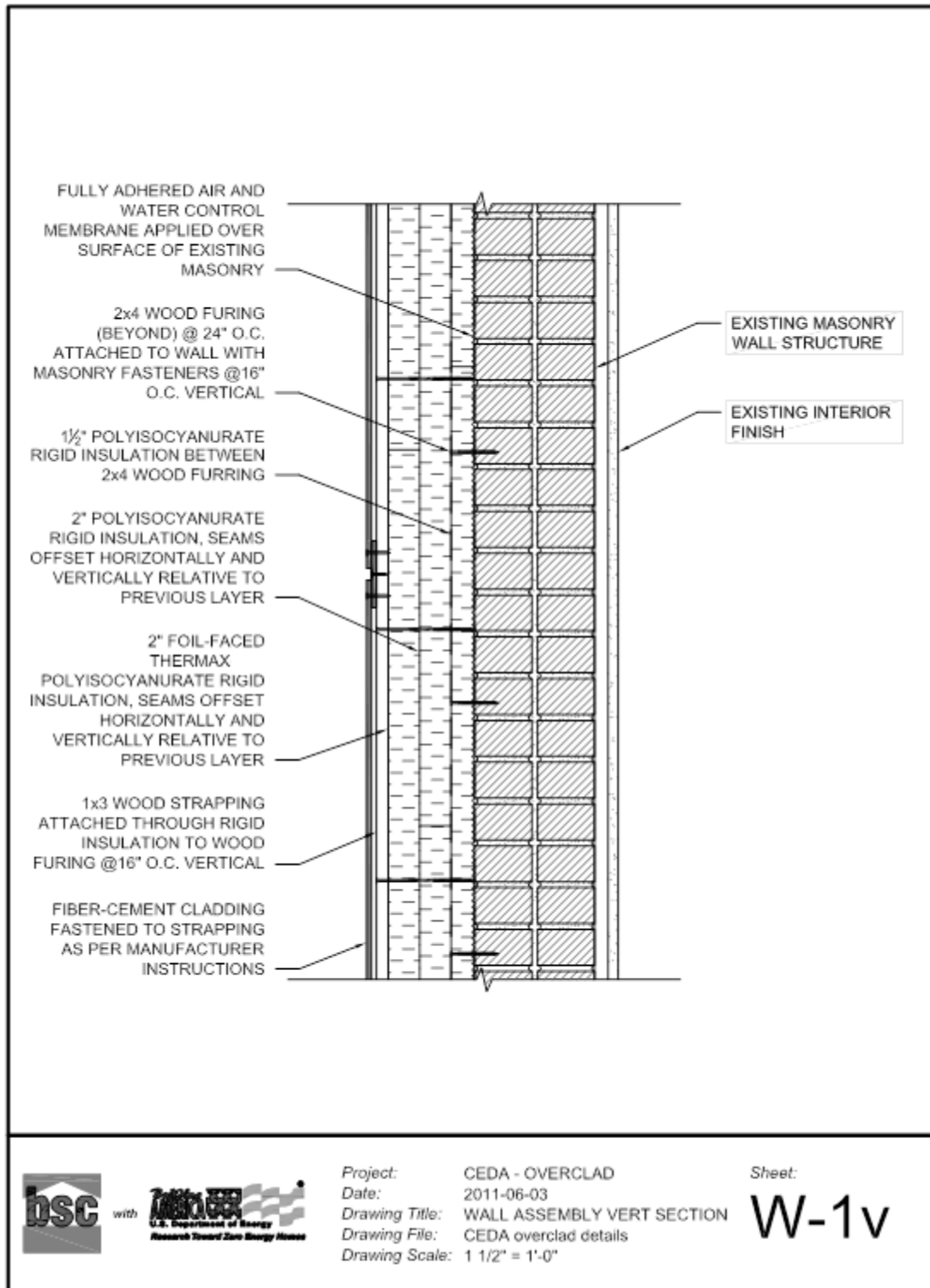


Figure 7. Schematic retrofit assembly, section view

BSC also prepared alternatives to this preferred approach in case the city building department found the team's preferred approach unacceptable from a fire risk perspective. Among these alternatives were assemblies that substituted semirigid mineral fiber insulation for polyisocyanurate and others that used metal hat channels in place of wood strapping for cladding attachment. Ultimately the project was able to proceed with an assembly involving wood strapping and extruded polystyrene (XPS) insulation behind fiber cement cladding.

The two candidate buildings that CEDA selected for participation in the research both have windows recently replaced and upgraded. Both buildings also have low-sloped roofs with brick parapet walls. BSC prepared schematic details for these buildings to address, in a generic fashion, window returns, the parapet, and the base of the insulation and over-clad assembly (see Appendix A).

The schematic details show a retrofit assembly consisting of (from face of masonry out):

- Membrane or elastomeric paint over existing masonry
- One layer of 1½-in. rigid insulating sheathing inset between 2 × 4 studs installed on the flat
- One layer of 2-in. rigid insulating sheathing with joints offset from underlying layer
- Wood furring strip attached through insulating sheathing to 2 × 4 stud installed against the existing masonry
- New cladding.

In this design, the “membrane or elastomeric paint” layer functions as both a water control and an air control membrane. Brick masonry is subject to capillary uptake of water. It is also known to pass water through small cracks such as sometimes form between mortar and brick units. The research team also does not believe that brick masonry provides robust and lasting airflow control. Since the brick is to be covered with insulating sheathing and cladding, preserving the appearance of the brick is not a concern. Thus, more readily available and less costly membranes could be used. Sealant is indicated as a substrate for the water and air control membrane at inside corners around window openings. The 2 × 4 studs provide a framing structure for support of the assembly. The wood furring strips provide support for the cladding attachment and provide a drainage and ventilation cavity behind the cladding.

The recently replaced and upgraded windows created a situation where the water management details needed to contend with (1) a window remaining in place, and (2) a window opening with unknown flashing condition. The details prepared show the water and air control membrane returning over the face of the window frame at the head, jambs and sill. The strategy employed is one of a face-sealed window opening rather than a drained opening as would have been preferred. In the face-sealed approach, water is controlled at the outer face of the assembly and sealants are relied upon to prevent water entry at joints. The approach does not have a provision to manage water that passes through the window unit or window frame. As noted in a communication from BSC to the CEDA project manager:

These details begin with the assumption that the existing window is performing and not leaking through the window frame itself. The details are designed to address the

window to wall interface and maintain continuity of the thermal insulation and drainage plane (WRB); however, they do not address water leakage through the frame itself. If there is leakage through the window frames, then the windows should be repaired or replaced.

The masonry wall does provide some safe storage capacity for minor water infiltration. However, a water leak could overwhelm this storage capacity. In the absence of flashing beneath the window or with improper flashing beneath the window, leakage through the window unit or window frame could be directed to where it would damage interior finishes. CEDA was apprised of the risk and determined that the long-term risk at the window openings is acceptable.

The details also show sealant between the trim and the bottom and sides of the existing window frame (Figure 8). The new window trim butting to the existing window frame provides a measure of protection for the sealant joint that is relied upon for water control (until such time as the window is replaced or reinstalled in a drained opening).

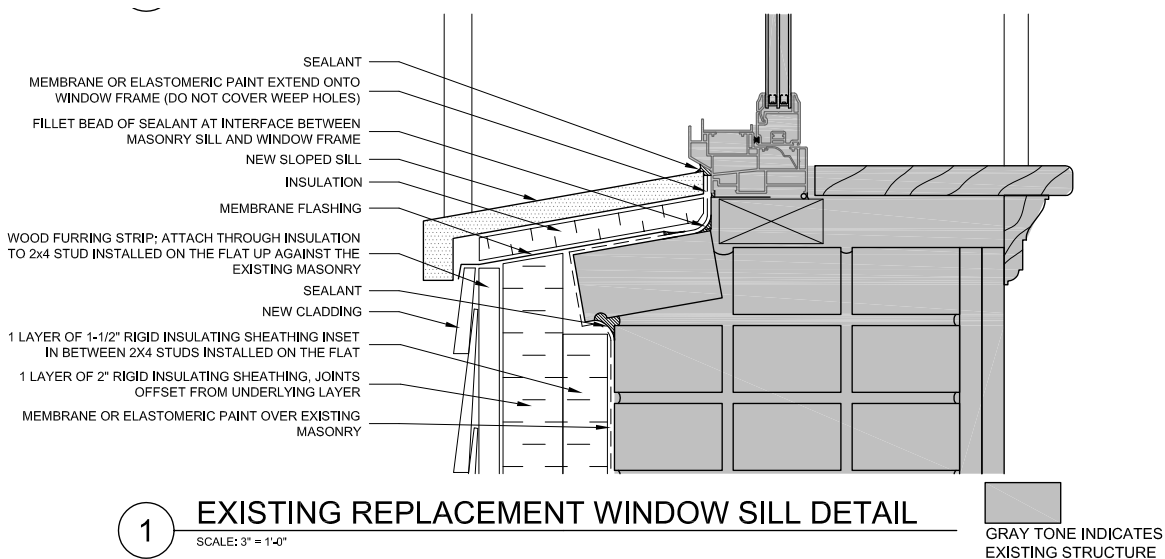
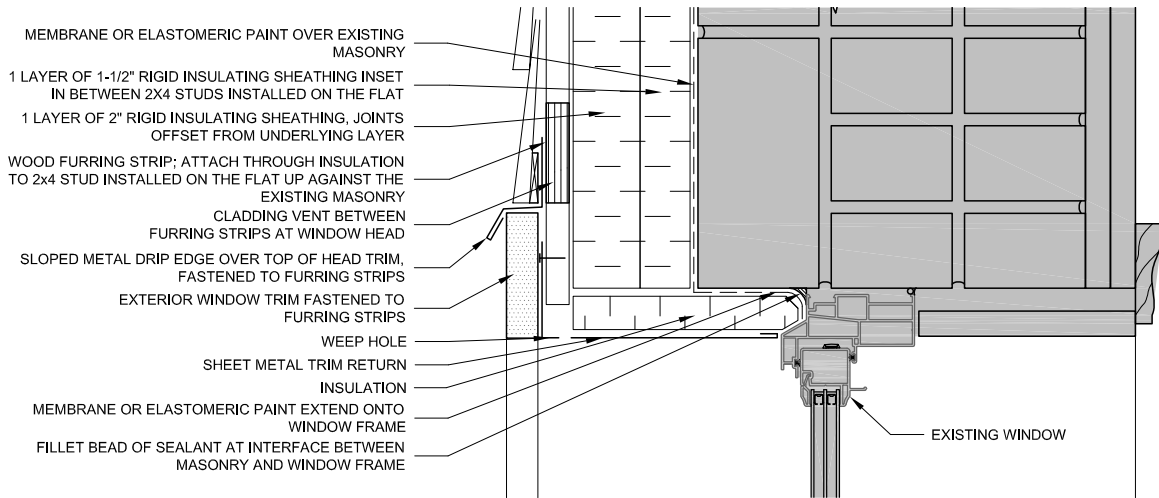


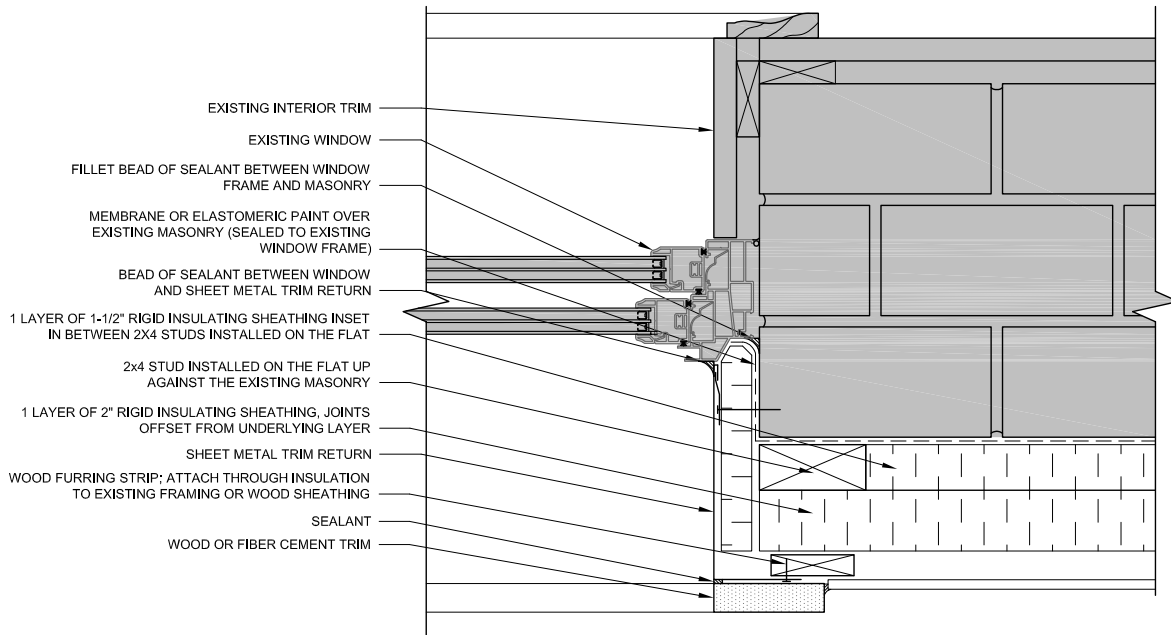
Figure 8. Window sill detail from schematic window details. Note that the water and air control membrane (dashed line at exterior face of brick) returns onto the window frame.

Regardless of whether or not leakage through the window frames will require near-term repairs, the expected service life of the window is not nearly as long as that of the wall assembly. The schematic window details anticipate replacement of the window at some point in the future. The window casing trim, window sill trim, trim returns and insulation at window returns are designed to be removed (and subsequently reinstalled) without disrupting the insulation and over-cladding assembly beyond the window opening. Removing these elements around the window opening provides access to the water and airflow control membrane of the insulation and over-cladding assembly. This makes it possible for a future window installation to establish a drained opening by installing pan flashing below the window and jamb flashing at the sides that properly integrate with the water and airflow control of the insulation and over-cladding assembly (Figure 9 and Figure 10).



2 EXISTING REPLACEMENT WINDOW HEAD DETAIL
SCALE: 3" = 1'-0"

Figure 9. Window head detail from schematic window details. Note that removing the window trim, trim return, and window return insulation exposes the water and air control membrane (dashed line at exterior face of brick) of the assembly.



3 EXISTING REPLACEMENT WINDOW JAMB DETAIL
SCALE: 3" = 1'-0"

Figure 10. Window jamb detail from schematic window details. Note that removing the window trim, trim return, and window return insulation exposes the water and air control membrane (dashed line at exterior face of brick) of the assembly.

The schematic details show a coil-stock trim return at the head and sides of the window opening in order to accommodate insulation at the window returns and to maximize the thickness of insulation at the returns. As noted by Baker (2012), insulating the returns of the masonry opening is very important for controlling flanking losses. Leaving the masonry surfaces of the opening returns uninsulated would amount to leaving significant thermal bypasses. The schematic details were developed for a generic window. Depending upon the configuration of the window, thickness of the window frame, and location of weeps through the window frame, the existing window might accommodate more or less insulation. In communication with the CEDA project manager, BSC established that the insulation level at the window opening returns would be no less than R-5.

For the parapet wall, the details prepared demonstrated a connection between the airflow control of the wall and that of the roof by a transition membrane that wraps over the top of the existing parapet structure and seals to both the membrane or elastomeric paint on the wall and, on the roof side of the parapet, the existing roof membrane. The approach represented in the detail also illustrated the need to remove the existing parapet cap as the existing cap would be inadequate after the wall is thickened with insulating sheathing (Figure 11). Wrapping the parapet with insulation also addresses a major heat loss liability represented by this masonry fin projecting above the surface of the roof (see Lstiburek 2008)

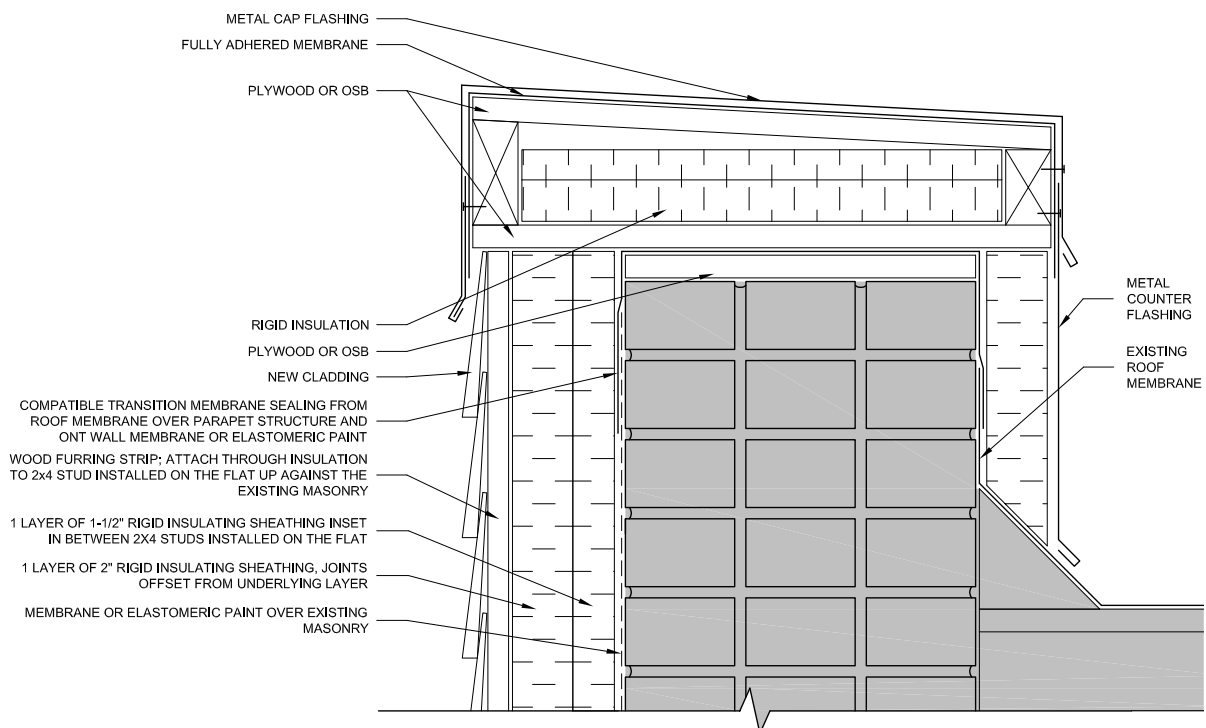


Figure 11. Schematic parapet detail. Note the transition membrane that connects the air control membrane of the wall (dashed line at exterior face of brick) to the existing roof membrane.

The parapet cap detail also evinces the opportunity to improve water management at the parapet wall with a new metal cap flashing and continuous adhered water control membrane over the top of the existing parapet. The roof side of the parapet is detailed to facilitate future replacement of the roof and connection of the new roof to the transition membrane.

CEDA used these drawings in soliciting bids from a selected group of contractors. Because the drawings were schematic and somewhat generic in nature—they were developed based on photos of the candidate buildings—the contractors needed to interpret how the design intent would be adapted to the particular conditions of the building.

BSC had envisioned developing a wider set of drawings and details specific to each of the buildings involved in the research. This would have helped bidding contractors better understand the work scope and functional intent. It also would have provided more specific initial direction to contractors selected to implement the work. Unfortunately, BSC was compelled to suspend work on the project due to uncertainty regarding funding and the continuation of the project. The schematic details that were used in soliciting bids became the drawings that contractors used to guide initial implementation of the retrofit assembly.

7 Assessment

7.1 Implementation Observations

This section will focus primarily on the question of feasibility as it relates to measures needed to achieve performance. Challenges encountered by the contractors during implementation are reviewed, as these are central to the question of feasibility.

7.1.1 Painted on Air/Water Control

Both contractors selected to perform the insulation and over-cladding work elected to use an elastomeric paint for the water and air control membrane at the face of the existing masonry (Figure 12 and Figure 13).



Figure 12. Commercially available elastomeric paint used by over-clad contractor
(Credit: Scott Sanders, CEDA).



Figure 13. (L) Elastomeric paint application at larger multifamily building. Note that sills of windows are not painted; (R) Elastomeric paint application at two family building.
(Credit: Scott Sanders, CEDA)

The contractor for the larger multifamily building applied the elastomeric coating in an initial application that did not bring the elastomeric coating onto the window frame, into window openings or onto window sills. The contractor correctly noted that these areas would require sealant to fill gaps, cracks, and joints, and further explained that sealant would be applied at a later point when the building is staged for the next item of work. A problem resulted from this plan: when the building was staged, the crew installed framing against the brick before installing the sealant and finishing the elastomeric coating application. As a result, framing that was installed over the face of the masonry obstructed access for painting and precluded establishment of a continuous water and airflow control membrane behind the insulation layer (Figure 14 left).



Figure 14. (L) Elastomeric paint application not complete around windows and portions of masonry surface obscured by wood framing; (R) elastomeric paint application at the two-family building covering the window sill and lapping onto the window frame
(Credit: Scott Sanders, CEDA)

Another sequence of operation issue emerged from obstructions not removed prior to the initial painting. Electrical conduit, gutters and rain leaders, cables, etc. that are present on the face of the building at the time of painting create potential areas of discontinuity in the control layer (Figure 15). Once these parts of the wall are obscured by framing or other components of the assembly, the opportunity for a continuous control layer is lost.

Contractors at both buildings found that elastomeric paint did not provide a continuous membrane over the uneven surface of the masonry. Small holes and depressions in the field of the masonry resulted in small voids in the paint coating. The elastomeric paint is applied with a roller. The contractors explained that spray application would not be advisable with the close proximity of other buildings and of vehicles. Both contractors agreed that back-brushing of the roller-applied paint would help fill the smaller gaps and imperfections, but both also pointed out that this would make the paint application much more labor intensive.

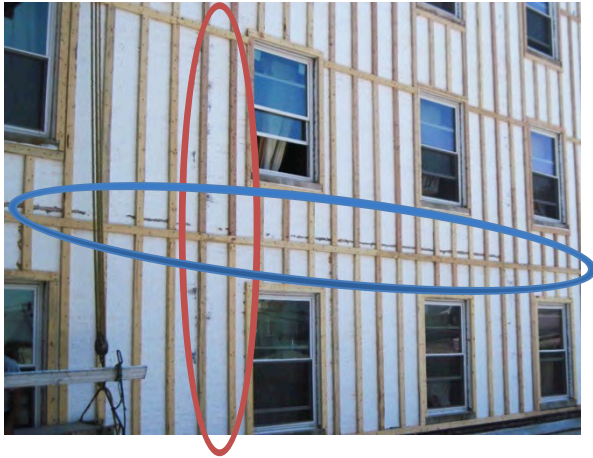


Figure 15. (L) Water and air control layer discontinuous at location of removed electrical conduit (blue circle) and gutter brackets; (R) satellite reception dish and associated cables create areas that will require touch-up to establish a continuous control layer with the elastomeric paint
(Credit: Scott Sanders, CEDA)

A more acute difficulty in establishing a continuous control layer was evident at joints and corners around window openings. In many instances the crew appeared to have difficulty in both sealing a joint and providing a smooth transition substrate for the water and air control membrane (elastomeric paint) (Figure 16 and Figure 17). In still other instances, sealant that had been installed previously may have provided a very irregular surface and/or failed to seal the joint. One could also observe many joints or cracks where sealant had not been applied. It is likely that these were more apparent after the elastomeric paint was applied. Returning to apply sealant after the elastomeric paint would be out of the general sequence.



Figure 16. (L) Window in masonry opening with previously applied sealant; (R) new sealant and elastomeric paint applied at window opening. Note persistent gaps at transitions.
(Credit: Scott Sanders, CEDA)



Figure 17. (L) Gap between masonry and lintel; (R) gaps at joints where sealant had not been applied as a substrate for the elastomeric paint
(Credit: Scott Sanders, CEDA)

7.1.2 Framing

7.1.2.1 Orientation of Framing

The contractors at both buildings exhibited conceptual difficulties in implementing framing in an exclusively vertical orientation. The contractors initially installed horizontal framing against the masonry at 8-ft intervals (Figure 18). The contractor for the larger building surrounded window openings with a picture frame of wood framing. The contractor for the smaller building installed a piece of horizontal framing at the top of window and door openings.



Figure 18. (L) Framing installed in a vertical orientation at 16 in. o.c. as well as horizontally at 8-ft increments in the field of the wall. Each window opening is also picture framed with the framing material; (R) Framing installed against masonry at two-family building with horizontal framing at top of window openings and at 8-ft vertical increments.
(Credit: Scott Sanders, CEDA)

After seeing photos from the field showing this framing condition, BSC advised the contractors, through the intermediary of the CEDA project manager, to stop installing horizontal framing in

the field of the wall and around windows. Both contractors installed framing in vertical orientation only for the field of the wall on the second of two treated walls at each building (Figure 19). One contractor continued to install framing in a horizontal position above windows and doors. The contractor for the larger building continued to install framing surrounding around each window.



Figure 19. (L) Framing installed at in a vertical orientation only in the field of the wall. Each window opening is picture framed with the framing material. (R) Framing installed against masonry at two-family building with horizontal framing at top of window openings but in a vertical orientation elsewhere.
(Credit: Scott Sanders, CEDA)

There are few concerns regarding the horizontal framing within the assembly. First, a horizontal member positioned across the water control layer has the potential to impede water from draining out of the system. Moisture that dwells in the system presents the risk of damage to moisture-sensitive materials—the horizontal pieces of wood framing in this case. Second, this represents unnecessary use of material and labor. Third, the unnecessary framing represents a small compromise to the thermal performance of the assembly. At a subsequent site visit, BSC demonstrated to the contractors how the horizontal framing was not at all needed for cladding and trim attachment.

7.1.2.2 Spacing of Framing

The schematic drawings of the retrofit wall assembly that BSC prepared for preliminary discussions with the City of Chicago Building Department indicated a 24-in. o.c. spacing for the furring installed to the face of the masonry (Figure 6 and Figure 7). However, spacing of the framing is not indicated on the schematic details that were included in the bidding package.

The contractor for the larger building spaced the framing installed against the masonry at 16 in. o.c. The contractor for the smaller builder also started with 16-in. o.c. spacing for this framing. Then this contractor determined that the cladding system could be supported on 24-in. spacing (Figure 20). After the installing the first level of framing against the first wall, the crew switched to 24-in. o.c. spacing to realize labor and material savings.



Figure 20. Strapping over insulating sheathing showing switch from 16 in. o.c. to 24 in. o.c. at the two-family building
(Credit: John Yi, CEDA)

7.1.3 Insulating Sheathing

Both contractors elected to use XPS rigid insulation board as the insulating sheathing (Figure 21). The contractors did not appear to have difficulty cutting and fitting the XPS to fit between the furring strips installed to the face of the masonry.



Figure 21. (L) Crews installing rigid insulation between furring; (R) second layer of rigid insulation installed over same section of wall as shown at left. Photo taken 1½ hours after photo at left. Finished first floor insulation extends another three window bays to the right of the image.
(Credit: Scott Sanders, CEDA)

Both contractors found the installation of insulating sheathing to be more efficient if they installed both layers of insulation at a particular section before moving on to the next section. This limited the offset of horizontal seams for subsequent layers to a few inches (Figure 22 below).



Figure 22. Offset of seams in successive layers of insulating sheathing. Offset for vertical seam is limited by the size of insulation boards and the spacing of framing.
(Credit: Scott Sanders, CEDA)

Because of the condition of the elastomeric coating over the rough brick surface and the presence of horizontal furring installed across the face of this water control layer, BSC advised the contractors to tape the seams in the outer layer of insulating sheathing so that it might function as a secondary water shedding layer behind the cladding. This proved to be at odds with the contractors' method of using the strapping to hold the insulation to the wall during installation. Providing continuous and effective taping of the seams would require intermediate fastening of the insulating sheathing so that the face of an area of sheathing could be taped prior to installation of the strapping. One or two screws with a washer or roof button per board would be enough to provisionally secure the insulating sheathing to the wall and allow the seams to be taped without obstruction by the strapping.

7.1.4 Strapping

Despite exhibiting a reticence to employ framing in a vertical orientation only, during installation of strapping over the insulation, the contractor for the larger building demonstrated comfort with limiting strapping to a vertical orientation (Figure 23 and Figure 24).



Figure 23. Wood strapping installed in vertical orientation only over face of insulating sheathing
(Credit: Scott Sanders, CEDA)



Figure 24. (L) Wood strapping with fastener used for attachment through rigid foam insulation to 2 x 4 framing; (R) longer size fasteners used to attach strapping through thicker rigid foam insulation layer at parapet

At the smaller building the contractor accepted the practice of using only vertically oriented strapping in the drainage plane after BSC demonstrated the approach during a site visit (Figure 25).



Figure 25. (L) BSC personnel explaining the attachment of trim to vertically oriented strapping; (R) the same window after the contractor reconfigured the strapping
(Credit: John Yi, CEDA [L] and Scott Sanders [R], CEDA).

7.1.5 Parapet

At both buildings, contractors found the parapet to be in worse condition than they had anticipated during the bidding process.

At the larger building, the parapet wall was significantly out of plumb. The bricks and mortar remained relatively intact after removal of the existing parapet cap. The crew foreman devised an ingenious method to allow the new cladding system to achieve a flat cladding surface while avoiding large gaps in the insulation layer (Figure 26). He found that the 2 × 4 furring could be bent and held by the masonry fasteners to the brick wall, and then pieces of beveled roofing insulation could be installed between the outer layer of insulating sheathing and the furring to true the outer layer of insulation and strapping. Longer screws were needed at this location to secure the strapping to the wood furring. The approach maintains a continuous layer of compressive resistance between the strapping and wood framing. The compressive resistance of the layer between the strapping and the wall is one of the mechanisms that enable the strapping to support the cladding weight over a thick layer of insulating sheathing (Baker 2012).



Figure 26. Beveled roof insulation used to true new cladding attachment at top of wall. Note that fasteners are left loose at the time of this photo.

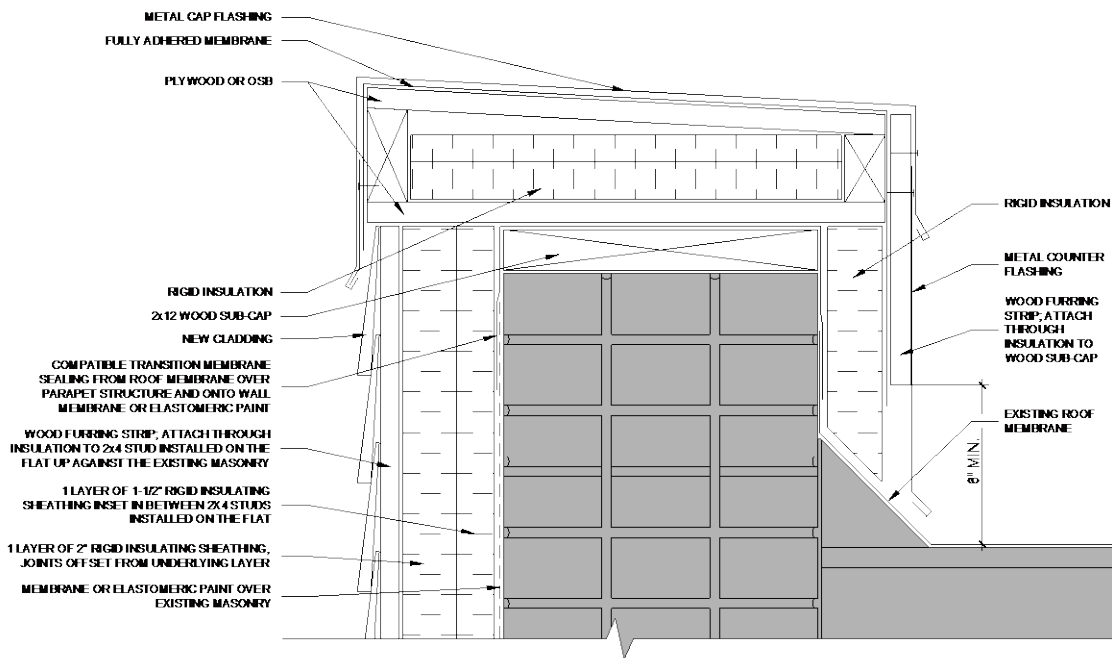
(Credit: Scott Sanders, CEDA)

At the two-family building, the contractor found several courses of brick beneath the parapet cap to be loose. The budget for the project did not permit any expansion of the contract to include resetting brick or repair to the parapet wall. The contractor proposed a modification to the schematic parapet detail to provide a wood frame that contains the parapet and supports cladding independent of the parapet. The contractor proposed using a 2 × 12 frame over the top of the parapet fastened to the wood furring attached to the face of the wall (Figure 27 Left). At the roof side of the parapet the contractor fastened oriented strand board (OSB) to the 2 × 12 (Figure 27 Right) as a substrate for attaching the insulation and metal counter flashing indicated in the schematic parapet detail (Figure 11).

The contractor's proposal provided a means to support the insulation, cladding, and new metal cap designated for this area. However, it did not provide for continuity of the airflow control from the wall to the roof. As seen in Figure 27, the vertical furring at the face of the wall prevents the membrane over the top of the parapet from wrapping onto the elastomeric coating on the face of the brick. BSC provided an alternate parapet detail for the contractor to implement (Figure 28). The contractor slightly modified this detail to install OSB to the inside face of the parapet. The perimeter of the roof was then attached to the face of the OSB before a transition membrane was wrapped over the parapet and onto the newly reattached roof membrane.



Figure 27. (L) Contractors mock up of frame over parapet using 2 × 12 attached to vertical furring attached to face of wall; (R) OSB attached to 2 × 12 at inside face of parapet.
(Credit: John Yi, CEDA)



2 PARAPET CONNECTION DETAIL
SCALE: 3" = 1'-0"

Figure 28. Schematic alternate parapet detail providing a frame over the top of the parapet. Note the transition membrane that connects the air control membrane of the wall (dashed line at exterior face of brick) to the existing roof membrane.

The finished parapet cover provided an assembly that allows for nondestructive removal of metal counter flashing and insulation in order to access the perimeter of the roof membrane for replacement (Figure 29). With the layers of insulation to both the inside and outside of the parapet, the new parapet was also noticeably wider than it had been previously.



Figure 29. Finished parapet cover at two-family building

The contractor at the larger building also encountered difficulty in providing a continuous transition of the airflow control over the top of the parapet from the wall to the roof surface. As seen in Figure 30, the initial installation of the transition membrane at the top of the parapet failed to connect to the elastomeric coating on the face of the wall and was not continuously adhered to the roof membrane at the inside face of the parapet.



Figure 30. (L) Transition membrane not connected to elastomeric coating at face of wall; (R) transition membrane not adhered to roof membrane at inside face of parapet

In discussing the treatment of the parapet with both contractors at the respective building sites, it was apparent that neither had approached the detail with an understanding of the function of the transition membrane. In the schematic design of the parapet treatment, the transition membrane is to provide a continuous airflow control transition and water control transition connecting the elastomeric coating on the face of the wall to the roof membrane. In other words, the transition membrane is intended to provide continuity between the air and water control functions of the roof and of the wall. Instead, at the initial implementation the contractors installed a piece that more or less provided water shedding at the top of the parapet.

Upon realizing the airflow control function of the transition membrane, both contractors realized the need to use wider or multiple pieces of adhered membrane to provide the continuity of airflow control. Some of the constructed assembly had to be removed at both building sites in order to allow the transition membrane to be installed. The contractors also wrapped the exposed ends of the parapet wall with an adhered membrane and insulation.

7.1.6 Base of Wall

The intent of the schematic detail for the base of the wall was to show contractors how the exterior insulation and over-clad assembly could be terminated at the base of the wall and how it could be protected from pests that might damage or nest in the assembly.⁶ The detail shows a cladding vent between furring strips at the base of the drainage and ventilation cavity. The detail also shows an insect screen that wraps over the base of the assembly from behind the insulating sheathing to over the face of the strapping and cladding vent (Figure 31).

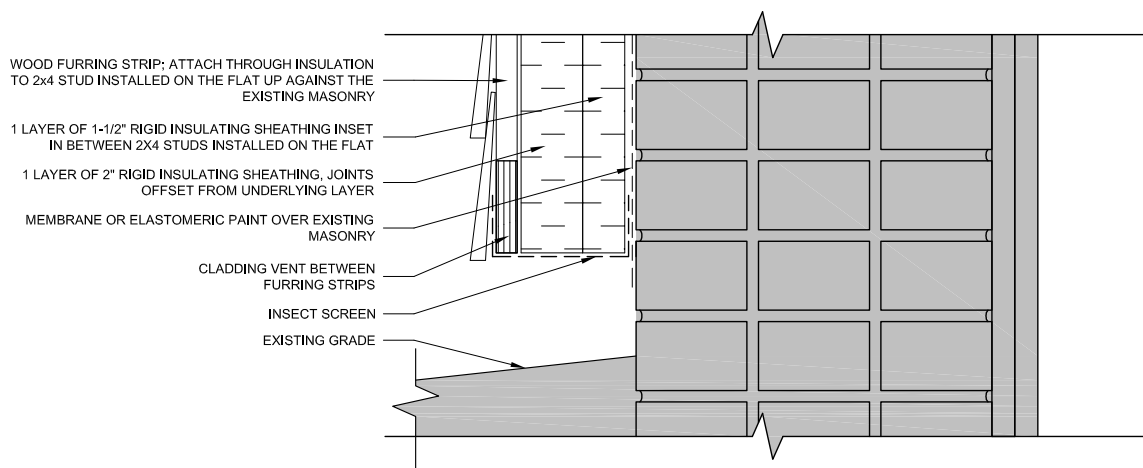


Figure 31. Schematic detail for base of insulation and over-clad assembly

⁶ The base of the exterior insulation and over-cladding assembly can be brought closer to grade than the cladding of a wood-framed structure. Because the underlying structure is solid masonry, the risk from pests is essentially limited to the exterior insulation. The materials of the exterior insulation and over-cladding assembly have robust tolerance for moisture exposure as long as the materials are permitted to dry. Therefore, the base of the assembly need only be protected against immersion in liquid water.

At both building sites, the contractor did not install screening material at the base of the wall prior to installing insulating sheathing. This required alternate methods for protecting the base of the assembly than shown in the schematic detail (Figure 32).



Figure 32. Base of wall with constricted access for attachment of screening
(Credit: John Yi, CEDA)

At the larger building, a conduit pipe at the base of the wall restricted access for attachment of the screening. Ironically, the horizontal furring, which was against BSC recommendations, at the base of the wall provided an attachment surface for a metal screen material. The cladding fastened over the wood strapping was loosened to allow the screen material to be fed underneath the cladding to wrap the exposed edge of the insulating sheathing.

At the smaller, two-family building, the insulation and over-clad assembly extended to very close to grade in order to allow the new cladding to align with the sills of the basement windows (Figure 33). This provided extremely limited working access for installation of any screening at the base of the wall. On the other hand, the concern for pest problems is heightened by having exposed edges of foam plastic insulating sheathing this close to the ground and with relative protection of the overhang created by the assembly.



Figure 33. Base of wall insulation and over-clad assembly very close to grade at the two-family building

During a joint CEDA/BSC site visit, the contractor proposed using perforated soffit material and brake forming it to obtain the desired profile for the closure and protection at the base of the wall. BSC reviewed the importance of providing a seal between brick and this closure piece to prevent bypasses between the brick and the closure piece. The contractor suggested using a continuous bead of roofing cement to seal the closure piece to the brick. BSC provided a revised detail for the base of the wall incorporating the contractor's suggestion as discussed and reviewed at the building site (Figure 34).

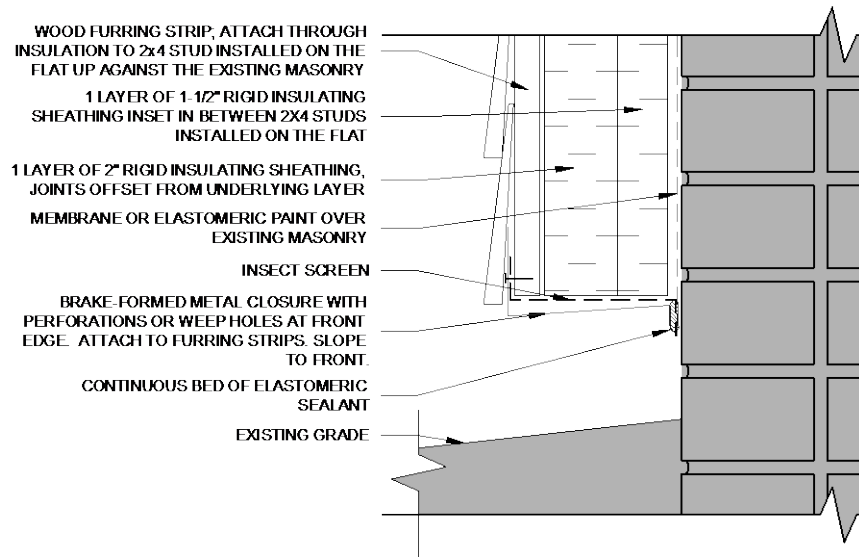


Figure 34. Excerpt of revised detail for protection at base of wall insulation and over-clad assembly

The closure piece implemented is sealed to the foundation wall and turns up over the outside face of the wood strapping. The perforated soffit material provides protection for the base of the assembly as well as screening for the ventilation cavity behind the siding (Figure 35).

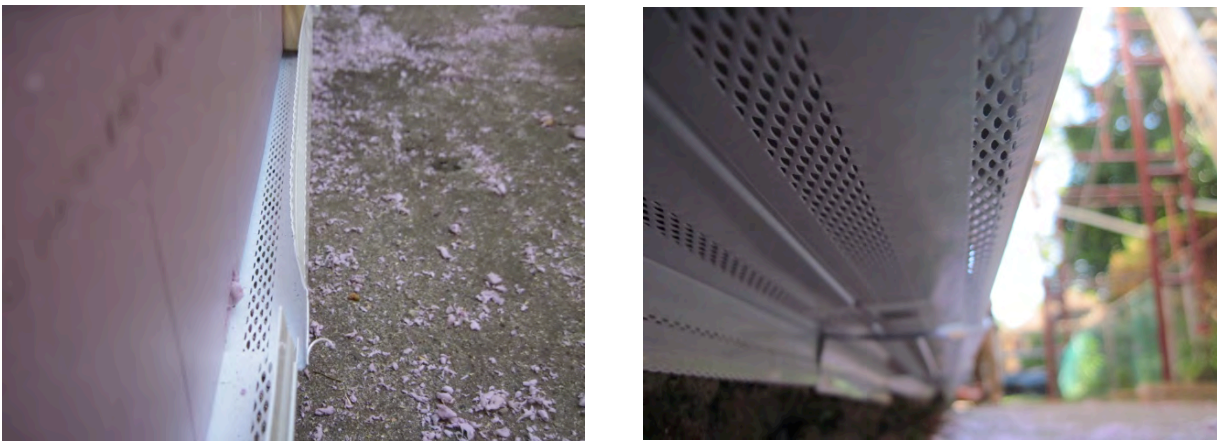


Figure 35. Perforated soffit material use for protection at base of insulation and over-clad assembly
(Credit: Scott Sanders, CEDA).

7.1.7 Window Surround

The windows at both over-clad sites had been replaced relatively recently and were to remain in place. The windows at the larger building had been replaced through a CEDA Wx program that

installed new triple-glazed, low-e, vinyl-framed windows. At the smaller building, the windows had been replaced by a program other than the CEDA Wx program two to five years prior to the over-clad project. The newer windows at the smaller building appear to be double-glazed, low-e, vinyl-framed windows. For both buildings, it is not known how the window openings are flashed or whether the windows are installed in a sill pan flashing. The windows appear to be face-sealed at the perimeters of the window frames.

The windows at the larger building are installed directly against the masonry opening and have a sealant joint between the masonry and the vinyl frame. At the smaller building, the windows are installed in a metal-clad trim/frame surround to the inside of the masonry opening (Figure 36).



Figure 36. (L) Window set directly in masonry opening at the larger building; (R) windows set in metal-clad trim/frame surround at the two-family building
(Credit: Scott Sanders, CEDA)

The difference in the window positions relative to the masonry openings led to a significant general difference in the installation of the insulation and over-clad around the windows. It appears that both contractors interpreted the window detail as indicating that the insulation and trim are to be returned to the first nonmasonry element in the window opening. At the larger building, the first nonmasonry element in the masonry opening is the vinyl frame of the window. When butted to the window frame, the insulation and return trim cover the sealant joint around the window (Figure 37). Covering the joint around the window frame is, in fact, the intent of the design. At the smaller building, the first nonmasonry element in the masonry opening is the metal-clad trim/frame surround. When the insulation and trim return are butted into this element, the joint around the perimeter of the window is left exposed (Figure 38).⁷

⁷ It should be acknowledged that the implementing contractor for this building reapplied sealant at the exposed joint around the window frame.



Figure 37. Return trim at the larger building butting into the vinyl window frame



Figure 38. Return trim at the smaller building butting into the metal-clad trim surround (blue arrows) leaving the joint around the vinyl window frame exposed (red arrow)

The implementation of the insulation and over-clad strategy at the window sill revealed additional challenges and the need for adjustments to the details. At the larger building, the contractor implemented a mockup of the window surround in preparation for a joint site visit by CEDA and BSC personnel. The mockup was implemented with a flashing membrane positioned over the insulation return at the sill (Figure 39). With the noted discontinuities in the elastomeric paint water control membrane, it is important that the adhered sill flashing at the window sill perform the function of preventing water from being absorbed into the masonry.



Figure 39. (L) Contractor mockup of window surround; (R) BSC personnel explaining placement of flashing membrane
(Credit: John Yi, CEDA)

The schematic details (Figure 40) show the flashing membrane at the sill extending out over the face of the cladding but covered by a sill trim piece. The contractor was concerned that the sill trim planned would not cover the edge of the membrane and opted, instead, to turn the sill flashing membrane onto the outer face of the insulating sheathing (Figure 41). This is acceptable given that the strapping cavity over the face of the insulating sheathing is designed and implemented to be a drained cavity and given that the cladding and trim system is expected to manage the bulk of incident rainwater.

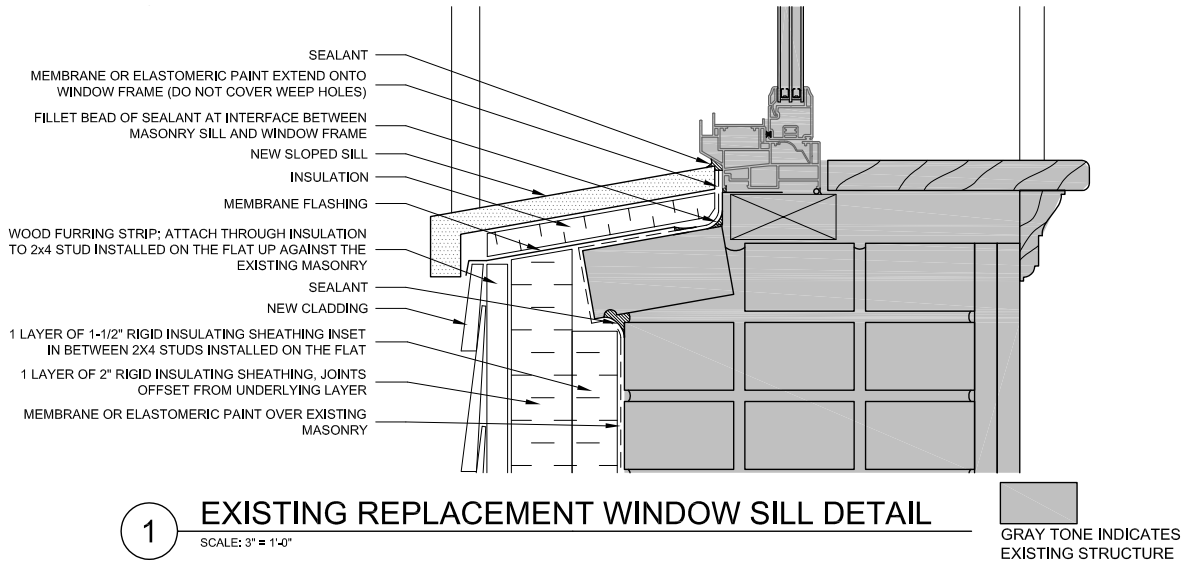


Figure 40. Window sill detail from schematic window details. Note that removing the window sill trim and window sill insulation exposes the water and air control membrane (dashed line at exterior face of brick) of the assembly.



Figure 41. Second mockup of window surround showing the flashing membrane placed beneath the insulation return
(Credit: Scott Sanders, CEDA)

During implementation of the window surround mockup, the contractor noted that 1 in. of rigid insulation returning at the sill would bring the sill trim very close to the weep holes of the window frame. The contractor purchased thinner rigid insulation boards for situations where the window opening could not accommodate 1 in. of rigid insulation.

The schematic details from which the contractors were working did not include an explanation of the implementation at the corner between the sill and the jamb. Indeed, the corners of the masonry openings represent the most vulnerability for water penetration. Ideally, control layers at the sill would turn up at the jamb and the control layers of the jamb would lap over the control layers of the sill to preserve a shingle lapping and to direct water away from the corner (Figure 42). The contractor for the larger building devised a sequence whereby the insulation return at the sill is installed prior to the insulation return at the jamb and then the sill trim is installed continuously across the sill insulation return prior to the jamb trim. On observation of the early phase of construction, it appeared that this sequence was not consistently implemented.



Figure 42. (L) Insulation return at the jamb installed before the insulation return at the sill. Note also that the sill flashing membrane does not extend over the outer face of the insulating sheathing. This was later corrected. (R) Sill trim installed after the jamb return trim. Sill extensions are actually cut around the jamb trim. Note that the window sill trim has a kick-out to direct water away from the face of the building.

At the smaller building the sills had a generally low slope that varied between windows. Some windows appeared to have a flat precast sill surface. This raised a challenge of achieving adequate slope for the rain-shedding layer of the window sill trim while providing adequate thickness of insulation and not blocking the weep holes of the window frame. The contractor had wrapped insulation returns into the jambs and heads of the windows on this building, but left insulation off the sills in anticipation of resolving the questions about treatment of the sill during a site visit by CEDA and BSC personnel. During this site visit, it was agreed that the contractor would use shims installed above the insulation return to provide a slope to the window sill trim and employ several different thicknesses of rigid insulation so that for each window. Insulation of the sill return could be as thick as could be accommodated without causing the sill trim to block the window frame weep openings. BSC prepared a revised window detail to document the approach agreed upon (Figure 43).

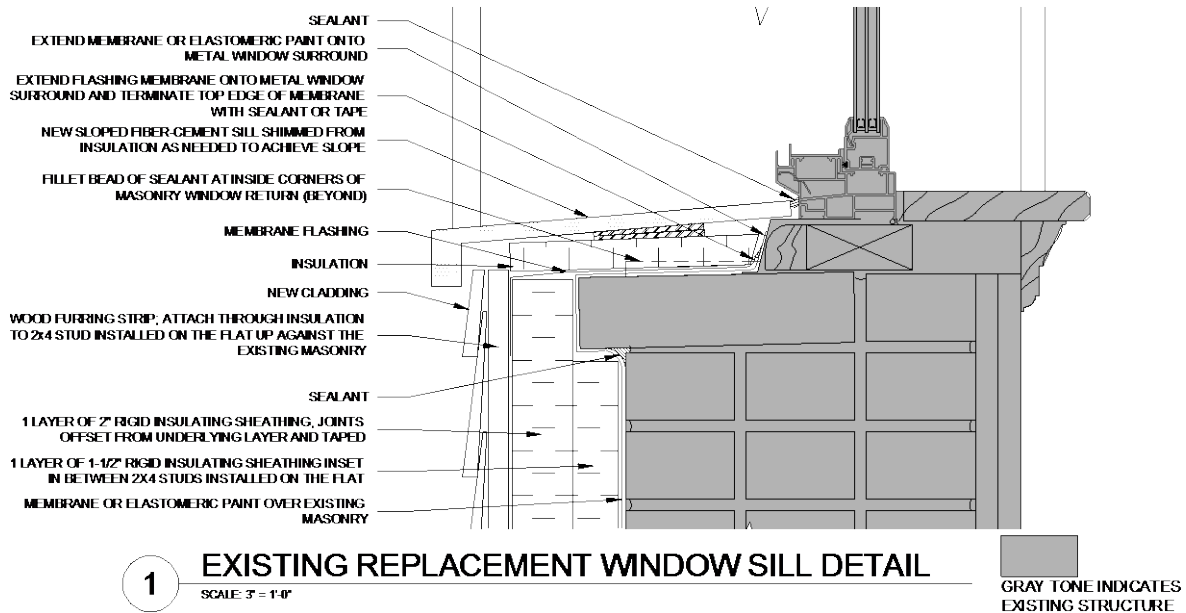
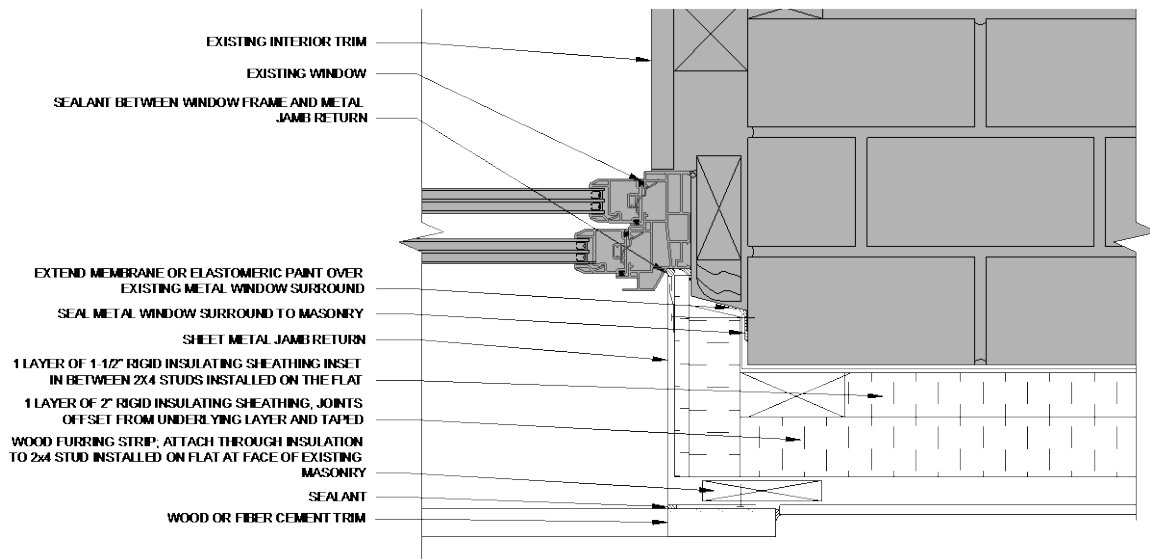


Figure 43. Revised detail for window sill treatment

This approach for the window sill had the advantage of protecting the sealant joint beneath the frame of the window. The slope given to the window sill trim allowed the trim to pass over the existing metal-clad trim/frame surround and butt directly to the vinyl window frame.

The revised details for the window that BSC prepared also showed insulation and trim returns butting into the vinyl window frame at the jamb and head of the window (Figure 44). However, because the contractor had already prepared the windows (with the installation of insulation returns and blocking) for trim returns that butt into the metal-clad frame/trim surround, the contractor was not willing to revise the approach for the jamb and head. The contractor did reapply sealant to the exposed joint between the vinyl window frame and metal-clad surround.



3 EXISTING REPLACEMENT WINDOW JAMB DETAIL
SCALE: 3" = 1'-0"

Figure 44. Revised detail for the window surround at the jamb

The window head represented an area where the contractors exhibited differing understandings of the need for water shedding and drainage.

Crews at the larger building did provide weep holes at the front edge of the window head return trim. However, on a joint site visit during construction of the first wall portion at this building, CEDA and BSC personnel found this trim to slope back toward the window in many cases. This back-slope at the head trim return is a concern because it would direct any water draining from the drainage cavity above the window or on the drainage plane (elastomeric coating on the face of the masonry) toward the window rather than away from the window opening.

CEDA and BSC personnel discussed the need for modification of the detail with the contractor and demonstrated the repair to ensure that the crew understood the intent of drainage and directing water away from the window. The repair of windows already trimmed required forming a new head return trim because the upturned leg was not long enough to provide a positive slope to the outside and still attach to the strapping at the head of the window. At the time the back-sloping head trim was discovered, the casing trim had been installed around most of the windows on one side of building. Rather than cut jamb casing trim to lower the head casing, the head return trim was lowered for a consistent 1½-in. reveal at the window head (Figure 45). This detail was carried over to the second side of the building.



Figure 45. (L) Window head return trim sloping toward the window; (R) CEDA personnel demonstrating the reconfiguration of the window head return trim

During the same CEDA/BSC joint site visit, it was discovered that the contractor had not installed a drip cap or diversion flashing above the head casing trim (Figure 46). Without this diversion flashing, the top of the head casing presents a horizontal shelf to impede water from draining down the cladding surface. In some locations, a poorly executed sealant joint between cladding and trim provided an opening where water would likely be directed behind the cladding. While CEDA and BSC personnel were on site, they worked with the crew to mock up a drip cap that demonstrates a positive slope to the outside and a drip edge to divert water away from the face of the building. A brake-formed drip cap was subsequently installed at each window head.

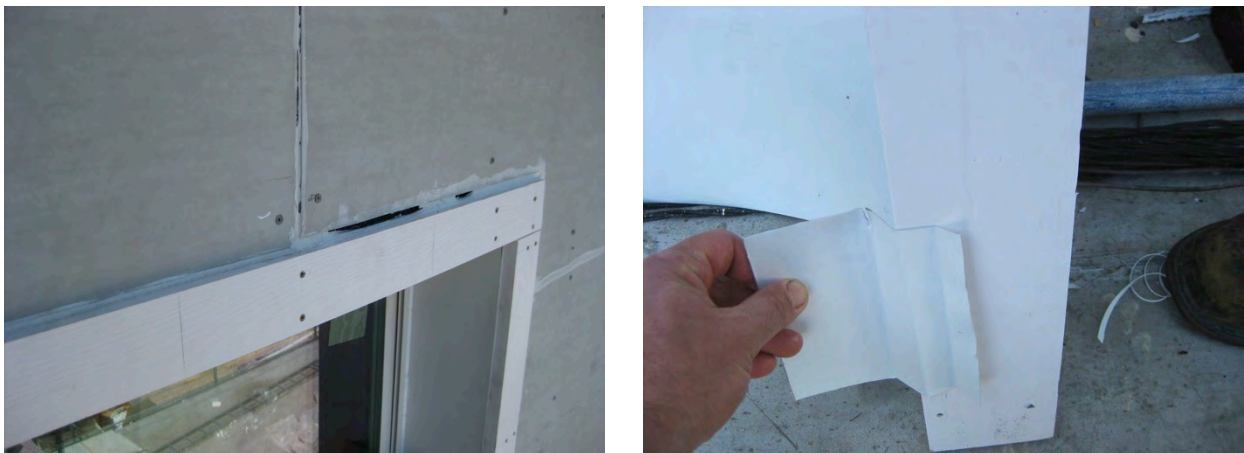


Figure 46. (L) Window head casing with no drip cap and sealant gaps; (R) Contractor project manager reviewing the drip cap flashing with the crew

At the smaller building, the contractor provided a trim return at the window head that not only sloped to the front but also had an extra bend at the front edge to channel water toward weep

holes (Figure 47). The contractor also installed a cap flashing above the head casing with a positive slope to the outside and a kick-out at the lower edge.



Figure 47. Window head return trim with profile channeling water to weep holes at the front edge

The experience of the insulation and over-clad implementation at both buildings reveals that greater attention is needed at the corner between the sill and the jamb of the window openings in order to ensure that this vulnerable interface is adequately protected against water intrusion. For example neither CEDA nor BSC received evidence that the sill flashing membrane turns up at jambs (or otherwise has end dams). It is also apparent that providing a termination for the top horizontal edge of a peel-and-stick type flashing is not common practice.

7.1.8 Cladding and Finish

The treated elevations of both over-clad projects present a clean and finished appearance. The contractor for each project involved the building owner in selection of cladding and trim colors (Figure 48 and Figure 49).



Figure 48. Finished side of the larger building



Figure 49. Treated wall at the smaller building striking a contrast with the untreated wall at the rear of the building

The scope for the larger building employed fiber cement panels (4-ft × 8-ft sheets) for the cladding. The contractor used cellular polyvinyl chloride (PVC) and metal coil stock for the trim. For the smaller building, lapped fiber cement siding was the specified cladding system. The contractor for this project used metal coil stock and color-matched cellular PVC for the trim. Some differences in treatment emerge from the different cladding types used.

The lapped siding for the smaller building was factory finished and primed on all sides. The panels used at the larger building were not factory primed. The contractor primed the back sides and edges of the panels prior to installation and then primed and painted the exposed face of the panels when these were installed on the building (Figure 50).

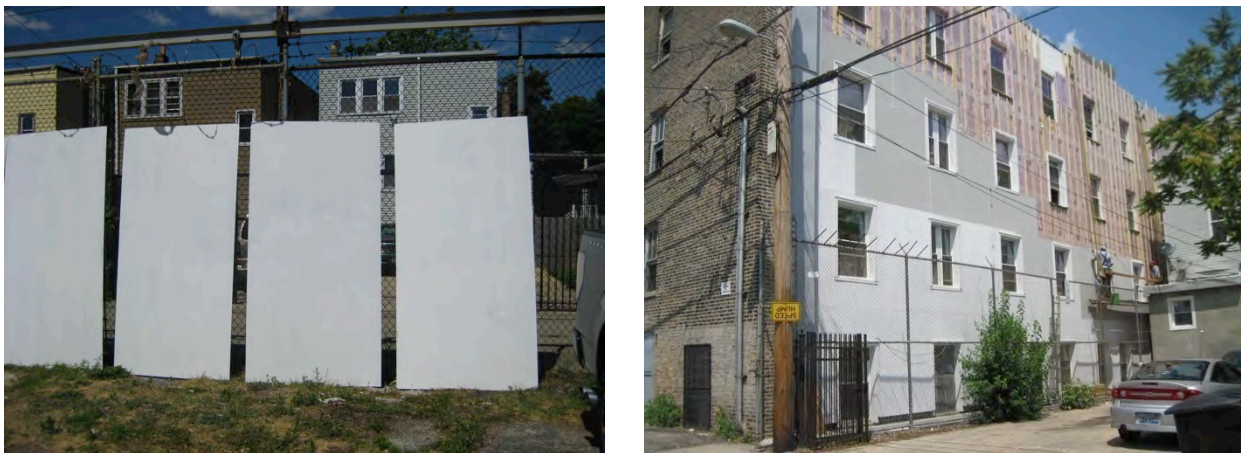


Figure 50. (L) Fiber cement panels back-primed prior to installation; (R) Progression of panel installation and face-priming at the second treated side of the larger building
(Credit: Scott Sanders, CEDA)

Early in the project, BSC raised a concern that the cladding system did not receive design attention from an aesthetic point of view. Specifically, the butt joints between panels are not coordinated with the geometry of the building by, for example, aligning with windows or other features on the treated elevation (Figure 51). The visible butt joints in the finished over-clad system might detract from the overall appearance of the installation (Figure 52 and Figure 53).



Figure 51. Caulked butt joints between 4 × 8 panels



Figure 52. Butt joints between the panels visible in the finished wall



Figure 53. Visible butt joints in the finished wall

While the lapped siding system is able to hide fasteners, the panel system installed employs exposed fasteners. The exposed fasteners might also detract from the appearance of the finished system, although this is subjective. The fiber cement panel manufacturer’s installation instructions included in the contractor submittal indicates “Z” flashing as an acceptable option for horizontal joints between panels. The contractor for the larger building where the panels were used elected, instead, to caulk both horizontal and vertical butt joints between panels (Figure 54). With the drainage cavity directly behind the panels, the “Z” flashing is not needed to relieve water behind the panels.



Figure 54. (L) Fiber cement lapped siding with fasteners at the top edge concealed by lap of subsequent piece; (R) fasteners for the panel cladding system exposed
(Credit: Scott Sanders, CEDA)

7.2 Cost Analysis

The contract cost for implementing the insulation and over-clad assembly amounted to \$23.65/ft² gross of treated wall at the larger building. The average for the three (of four total) lowest bids for this project amounted to \$25.31/ft² gross. For the smaller building, the implementation cost amounted to \$11.10/ft² gross of treated wall with the average of the three lowest bids at \$14.43/ft² gross of treated wall. Wrapped into these cost figures is the cost for treating or remediating the parapet and installing a new cap.

After each implementing contractor either completed the work or completed a substantial portion of the work, the implementing contractors were asked to provide an estimate for the cost of implementing the insulation and over-clad assembly. This estimate was to reflect experiences gained during implementation of the work. This was deemed useful information, as neither contractor (nor any of the bidding contractors) had implemented a similar assembly. Interestingly, both implementing contractors estimated a unit cost that was close to their original bid and lower than the average of the three lowest bids. This is taken as validation of the contract cost as representing a mature market unit cost for similar work.

During interviews with the implementing contractors, the contractors indicated that working access at the building site and height of the building are significant factors in the cost of working on the exterior of a building. Occupational safety regulations permit access by ladder for work on structures up to two stories in height. Above this height, staging or a lift mechanism would be required, thus significantly increasing the cost of the job and the resulting unit cost for the measure. The contractors involved in this research project indicate that a mechanical lift operating from the ground is the least costly and most flexible means to perform exterior building enclosure work above two stories. Use of such a lift, however, would require a relatively large area of clear and level ground adjacent to the building. Such access is not unheard of in urban environments, but is also certainly not to be expected as a general condition.

The site of the larger building accommodated some work from ladders; however, most of the work above the first level required the use of suspended staging. At the smaller building, work could be performed with ladder access on one side of the building. On the other side, pipe staging was needed due to the tight spacing between the subject building and the adjacent building. In fact, even the pipe staging was made feasible only by the fact that the owner of the subject building also owns the adjacent building and thus was amenable to allowing working access from the adjoining property. Without this accommodation, the side setback would have been insufficient to allow pipe staging to be erected.

One of the contractors implementing the over-clad work provided an estimate of the assembly cost under four different basic scenarios of building height and access. Table 1 shows the impact of building height and access on the unit cost estimates provided by this contractor.

Table 1. Height and Access Impact on Insulation and Over-Cladding Costs

Scenario	Unit Cost Impact
Two stories, easy work access	Baseline
Two stories, difficult access	+ 9%
Three or more stories, easy work access	+ 35%
Three or more stories, difficult access	+ 39%

The unit costs reflected in bids for the larger building represent a premium of approximately 75% over unit costs reflected in bids for the smaller building. This premium is greater than would be suggested by Table 1 for generalized height and access parameters. Perhaps location also factored in to the contractors' bids. The smaller building is located in a modest-income residential neighborhood. The larger building is located in a more densely developed mixed-use urban area. The larger building is also enclosed by at least one layer of 12-ft high, razor wire-topped chain link fencing. To a contractor evaluating the project, this fencing might indicate greater risk to security of materials, crew vehicles, etc., which would in turn, risk increasing costs to the contractor.

As discussed in Section 4, the costs attributable to the exterior insulation strategy are inextricably linked to nonenergy benefits. Therefore, it is not reasonable to compare estimates of energy cost savings directly to component costs to derive a measure of cost effectiveness. It is, however, useful to compare the assembly as implemented to an over-cladding strategy decidedly not aimed at achieving energy benefits. Where the comparison includes components of the exterior insulation and over-cladding assembly, then the cost increment between these two different assemblies might be associated with a narrower scope of associated benefits.

Conceivably, fiber cement siding could be installed on furring strips attached directly to a masonry exterior. The thermal benefit of such a strategy would be almost inconsequential. The noninsulated over-cladding would entail certain nonenergy benefits to the building. These benefits, while not quantifiable, can be enumerated. Table 2 below compares the potential nonenergy benefits expected from a noninsulated over-cladding strategy to those of the over-cladding plus insulation strategy implemented in this study. The noninsulated over-cladding strategy in this comparison involves fiber cement siding attached to furring strips or metal channels attached directly to a masonry wall. This hypothetical strategy is compared to the assembly implemented in this research project.

Table 2. Nonenergy Benefit Comparison

Nonenergy Benefit	Noninsulated Over-Cladding^a	Exterior Insulation Plus Over-Cladding^b
Water Management	Depending on flashing and water diversion details, improved by addition of <ul style="list-style-type: none"> • Rain-shedding cladding • Drainage cavity 	Superior water management achieved by addition of <ul style="list-style-type: none"> • Rain-shedding cladding • Drainage cavity • Multiple layers of insulating sheathing with face of outer layer taped • Water and air control membrane integrated with flashing of wall
Weather Exposure	Reduced weather exposure for masonry. May significantly extend the service life of mortar (reduce the need for repointing) While the need for repointing is reduced, access for repointing is significantly encumbered.	Reduced weather exposure for masonry. May significantly extend the service life of mortar (reduce the need for repointing) While the need for repointing is reduced, access for repointing is significantly encumbered. Freeze-thaw risk is virtually eliminated.
Comfort	Limited to no benefit	Improved radiant comfort
Aesthetics	Subjective	Subjective

^a Fiber-cement siding installed over strapping

^b Fiber-cement siding installed over strapping, two layers of rigid insulating sheathing, and water and air control membrane

While not necessarily a benefit, the noninsulated over-cladding strategy presented in this comparison maintains the ability of the masonry wall assembly to dry to the exterior through both diffusion and air leakage. The exterior insulation plus over-cladding assembly provides very limited to virtually no ability of the masonry to dry to the exterior. With the superior control of exterior water loading offered by the insulated system and with adequate control of internal moisture loads, there would be no benefit to the masonry being able to dry to the exterior.

Using R.S. Means data for the Chicago area, the installed cost of the above described noninsulated over-cladding can be estimated at approximately \$5.50/ft². It is assumed that this cost would be impacted by the same factors that yielded the variation in costs collected through the research project for implementation of the insulated over-clad assembly. The cost data collected imply that work on the exterior wall at the larger building entail a 75% unit cost premium relative to the smaller building. Applying this same premium to the estimated cost for the noninsulated over-cladding strategy, the insulated over-clad assembly is estimated to represent a \$9–\$15.60/ft² cost increment over the noninsulated over-cladding strategy. This cost increment could be associated with the resulting energy cost savings aggregated with the relative nonenergy benefits enumerated in Table 2. It would not be appropriate to associate this cost increment with energy cost savings alone.

Through interviews and during site visits by BSC, the implementing contractors and construction crews provided suggestions for reducing the cost of the insulation and over-cladding assembly. Both implementing contractors indicated that the strategy was particularly labor intensive. The parapet and details surrounding windows were identified as areas requiring particularly high levels of labor input. While BSC did not field suggestions of specific alternatives for treating the windows and the parapet, certainly a building without a parapet (i.e., a building with a steep slope roof) would avoid that cost.

Both contractors suggested that removing the elastomeric paint layer as a cost saving adjustment to the strategy. One contractor suggested that eliminating the paint layer would reduce the unit cost by more than \$2.50/ft². This cost reflects the need to generally stage and access the building separately for this step of the implementation.

The insulation and over-cladding strategy implemented at the larger building employed fiber cement panel siding comprising 4-ft × 8-ft sheets of material. The contractor explained that managing large sheets of material on the side of a building entailed certain challenges (especially in the “Windy City”) and required a greater number of personnel to be on site during installation to handle material both on the ground and on staging. The contractor suggested that lapped siding would represent cost and schedule advantages. When asked, the crew at this project agreed that the larger panels entailed installation challenges but also suggested that these are balanced by the larger area covered by each panel allowing the cladding operation to progress more quickly. A lapped siding alternative was among different scenarios for which the contractor for the larger building offered cost estimates. These estimates indicate that the lapped siding would result in savings of up to \$0.55/ft² or approximately 3% of total unit cost for the scenario involving three or more stories and difficult access.

One of the implementing contractors suggested that the insulation and attachment substrate for the siding could be achieved by nail base panels (OSB laminated to rigid foam insulation). This contractor estimated that the cost for an assembly composed of 3-in. thick insulated nail base panels, house wrap, and fiber cement siding would have a unit cost savings of approximately 24% relative to the assembly implemented through the research project. This alternative assembly for which the estimate was provided does not include the water and air control membrane at the face of the brick or the strapping beneath the cladding. Including these components would be necessary for the alternative assembly to provide a similar level of water management and durability performance. Including these components in a system based on the insulating panels would significantly diminish any relative cost advantage.

Both implementing contractors suggested the use of closed-cell spray foam on the exterior of the building as an alternative to the adhered water and air control membrane and rigid board insulation. The rationale for the suggestion was time (schedule) and labor savings. Both contractors offered an estimate of the cost of this alternative approach. The contractor for the larger building estimated that the closed-cell spray foam-based strategy would represent a savings of 1%, the contractor for the smaller building provided an estimate representing a 12% savings relative to the retrofit assembly as implemented.

7.3 Performance Assessment

Blower door testing was used to measure pre- and post-retrofit air leakage at the smaller insulation and over-clad building. Blower door testing was not employed at the larger building

because whole-building testing was not feasible given the occupancy situation and size of the building. Testing of individual units would have been feasible, but, given the significant and variable interunit leakage, it is unlikely that testing of individual units would have provided a robust signal as to the impact of the exterior enclosure measure.

At the initial assessment visit wherein the smaller building was scoped for eligible Wx services, the CEDA assessor measured an air leakage rate of 4,270 cfm at 50 Pascals (cfm50), which corresponds to 8.7 ACH50 (excluding the basement volume) and 6.4 ACH50 (including the basement volume). At a final work inspection visit, CEDA personnel measured the air leakage rate to be 2,952 cfm50, which corresponds to 6.0 ACH50 (excluding the basement volume) and 4.4 ACH50 (including the basement volume). This represents a reduction in measured air leakage of approximately 30%.

A 30% reduction in air leakage would seem very impressive, especially considering that the insulation and over-clad assembly affected less than 50% of the above-grade enclosure area or only about 60% of the above-grade exterior wall area.

In fact, other Wx work was performed in conjunction with the exterior insulation and over-clad work. The other Wx work performed includes installation of compact fluorescent lamps in some of the fixtures, a “major bypass” air sealing package, and installation of door sweeps and weather stripping. The “major bypass” air sealing package refers to a standardized package of air sealing work used in the CEDA Wx program. CEDA Wx program work orders describe this package with standardized language that specifically indicates areas for air sealing as follows:

- **Joist spaces under kneewall in finished attic areas.** Create a rigid seal under the kneewall using rigid material (drywall, 1-in. rigid foam, hard board, etc.). Cut and place between the ceiling joists. The perimeter of the barrier should be sealed with expanding spray foam (two-part foam).
- **Kitchen or bathroom interior soffits.** Seal the top of the soffit with a rigid barrier that can support the weight of required insulation, fasten and seal to ceiling joists and soffit framing with spray foam or caulk.
- **Two-level attics in split-level houses.** Seal the wall cavity with a rigid barrier and seal surroundings with spray foam or caulk.
- **Top of balloon-framed interior and exterior walls.** Seal with a rigid barrier and air seal with caulk or spray foam.
- **Fur cavity on masonry buildings.** Seal the cavity with two-part foam around the perimeter of the attic or roof.
- **Joist penetrations on masonry bandjoist.** Seal the perimeters of penetrations with spray foam.
- **Chimneys and fireplaces.** Seal the chimney and fireplace and the area around them with sheet metal (minimum 28 gauge thickness) and seal with high temperature sealant.

- **Soil stacks, plumbing pipes, and open plumbing chases.** Seal joints with spray foam or caulk. If a joint is too large, stuff with fiberglass insulation or cover with a rigid barrier and foam over the top.
- **Housings of exhaust fans and recessed lights.** Caulk joints where housing comes in contact with the ceiling.
- **Duct boots and registers.** Caulk or spray a foam joint between the duct boot or registers and ceiling, wall, or floor finish if ducts are located in the attic, crawlspace, or attached or tuck-under garage.
- **Wiring and conduit penetrations.** Seal the joint with caulk or spray foam.
- **Duct chases.** Smaller openings may be spray foamed or caulked. For larger chase openings, cover with a rigid barrier and seal to ducts and ceiling materials with caulk or spray foam.
- **Bathtubs and shower stalls.** Seal from the foundation with spray foam. For larger areas, fasten and cover with a rigid material and seal with spray foam
- **Other openings in the air barrier.** Seal with a rigid material, seal with caulk or spray foam depending on the size of opening.

Because this is a standardized or “boilerplate” scope, not all of the items indicated would be applicable to a given building. For example, work items relative to “joist spaces under kneewall,” “two-level attics,” “duct boots and registers,” and “duct chases” would not apply to the two-family building included in this research project.

The remaining items listed in the Wx air sealing work scope would be generally expected to have a significant aggregate impact on air leakage. It is worth noting that most of the remaining items on this list that might apply to the two-family over-clad building also happen to address air leakage between conditioned space and an attic and that the attic may not be well connected to the exterior. This particular building has a shallow attic beneath a low-sloped membrane roof. Air leakage through the membrane roof is expected to be of very small magnitude. The deliberate provisions for venting of the shallow attic space were also observed to be quite limited. Given the configuration of the attic and of the roof it is conceivable that the initial air leakage through the attic would have been a relatively minor component of the total measured air leakage.

Unfortunately, it is not possible to differentiate between the air leakage reduction resulting from the Wx work on the one hand and the insulation and over-cladding scope on the other, because both of these were implemented in the time between the prework blower door measurement and the postwork blower door measurement. A case can be made, however, that the exterior insulation and over-cladding treatment rendered leakage across the attic floor less significant in overall leakage, as connections between the attic and exterior are reduced. The incidental leakage through the exterior walls surrounding the attic and through the parapet would be expected to be blocked by the exterior insulation and over-cladding treatment. By extension, comprehensive treatment of the exterior wall system (all four sides) in a building with a low-sloped roof would essentially bring the attic within the pressure boundary. It follows, then, that virtually all of the

air leakage reduction potential from treating the attic floor would be subsumed by a comprehensive treatment of the exterior wall system.

7.4 Simulation Analysis

7.4.1 Description of Simulation Models

The simulation analysis is performed to provide a perspective on the energy performance impact of the exterior insulation and over-cladding measure. The analysis employed the BEopt energy simulation tool. The analysis software is also used to illustrate the energy performance impact relative to the total measure cost. While the implementation of the measures was limited to portions of two buildings, the simulation analysis evaluates a scenario of a more comprehensive enclosure retrofit.

Because the focus of the study is an enclosure measure, the primary focus of the simulation evaluation is the relative impact of the measure on heating and cooling energy use. The total simulated energy usage reflects influences of systems and equipment that are outside the purview of the current study. In a sense, the total energy usage, reflecting internal loads and mechanical system efficiencies, may cloud the evaluation of the enclosure measure. Nonetheless, some approximation of these other loads and systems is needed to be able to project a general case of the net impact that the enclosure measures might have on a building in operation.

Some abstraction was needed to model the performance of a multifamily building using the BEopt simulation tool. The tool is set up to model single-family occupancies. Rather than attempting to create a model of a suitably representative single dwelling unit within the building, the simulation analysis pursued representation of the entire building by scaling various inputs to reflect the occupancy within the building. The model of the smaller building employed scaling of inputs to represent a two-family occupancy. The larger building includes approximately 84 single-occupancy rooms with shared facilities at each floor; the occupancy and internal load intensity were estimated as equivalent to 28 single-family units. The internal gains from major appliances were adjusted to represent the occupancy and expected use intensity within the building enclosure. This was intended to provide a rational representation of the additional cooling load and offset to heating load resulting from the multifamily occupancy. The modeling confirmed our expectation that the effect of internal gains on heating and cooling load is not prominent in the Chicago climate and for the level of enclosure thermal performance evaluated.

The simulation reflects another significant abstraction in that the same thermal modifications are modeled for all exterior walls of the building. The exterior insulation and over-cladding strategy evaluated in this research is not necessarily intended as a system to be applied on all sides of a building. In fact, given the articulated and finely executed street façade typical to brick masonry buildings in Chicago, the exterior insulation and over-cladding strategy would typically only be considered for the non-street elevations. In other words, while budget constraints limited the implementation of the strategy to portions of two buildings, even with unlimited funding, the research team would not have proposed implementing the strategy on the front side of these buildings. BEopt does not currently support different levels or types of insulation on different

walls. The BEopt models presented here simulate only the hypothetical scenario in which it is possible to treat all walls in a substantially equivalent manner.⁸

BSC prepared simulation models to represent each of the buildings involved in the research study. Major inputs used to describe the building components are listed in Table 3 and Table 4.

⁸ It is not inconceivable that the street façade of the building would be treated to approximately equivalent performance. In fact, the exterior insulation and over-cladding assembly was initially conceived as a complement to interior insulation of masonry as evaluated by Straube et al. (2012) that could certainly achieve similar levels of performance. Because of the complex needs of buildings and building owners, a variety of enclosure strategies are often needed to achieve comprehensive enclosure upgrades.

Table 3. BEopt Modeling Inputs for Two-Family Building

Building Component	Baseline Parameter	Parameter Upgrades and Alternatives Evaluated	Cost of Upgrade	Cost Source
Infiltration	8.7 ACH50	6 ACH50 (30% reduction)	Included in other costs	N/A
Attic/Roof Insulation	R-10 continuous	R-40 continuous	\$2.82/ft ²	BEopt library
Above-Grade Walls	6-in. hollow concrete masonry unit (CMU) (selected to represent uninsulated 3 wythe brick masonry)	Step 1: 6-in. hollow CMU with R-4.6 continuous insulation exterior (selected to represent 1½-in. XPS between wood 2 × 4 on flat at 24 in. o.c. and cladding)	\$11.12/ft ²	Derived from contractor's postconstruction cost estimates
		Step 2: 6-in. hollow CMU with R-15.7 continuous insulation exterior (selected to represent Step 1 assembly with addition of continuous 2-in. XPS layer and strapping to support cladding)	\$14.82/ft ²	Derived from contractor's postconstruction cost estimates
		Step 3: 6-in. hollow CMU with R-25.4 continuous insulation exterior (selected to represent Step 2 assembly with addition of 2 nd continuous 2-in. XPS layer)	\$16.82/ft ²	derived from contractor's postconstruction cost estimates
Windows	U = 0.34, solar heat gain coefficient = 0.30 (estimated representation of recent Wx window upgrade)	No upgrade	N/A	N/A

Building Component	Baseline Parameter	Parameter Upgrades and Alternatives Evaluated	Cost of Upgrade	Cost Source
Basement	Uninsulated	No upgrade (in actual application, the exterior wall treatment would extend to 3–4 ft of above-grade basement wall)	N/A	N/A
Refrigerator	2 units, 960 kWh/yr total	No upgrade	N/A	N/A
Stove	2 units, 56 therms/yr total	No upgrade	N/A	N/A
Lighting	Building Americaq Benchmark	No upgrade	N/A	N/A
Heating System	80% annual fuel utilization efficiency, gas-fired boiler	No upgrade	N/A	N/A
Cooling System	10 seasonal energy efficiency ratio window units	No upgrade	N/A	N/A
Ventilation	No mechanical ventilation	No upgrade	N/A	N/A
Domestic Water Heater	Standard gas-fired, energy factor 0.59	No upgrade	N/A	N/A

Table 4. BEopt Modeling Inputs for Larger Multifamily Building

Building Component	Baseline Parameter	Parameter Upgrades and Alternatives Evaluated	Cost of Upgrade	Cost Source
Infiltration	7.2 ACH50	5 ACH50 (30% reduction)	Included in other costs	N/A
Attic/Roof Insulation	R-10 continuous	R-40 continuous	\$2.82/ft ²	BEopt library
Above-Grade Walls	6-in. hollow CMU (selected to represent uninsulated 3 wythe brick masonry)	Step 1: 6-in. hollow CMU with R-4.6 continuous insulation exterior (selected to represent 1½ in. XPS between wood 2 × 4 on flat at 24 in. o.c. and cladding)	\$15.96/ft ²	Derived from contractor's post construction cost estimates
		Step 2: 6-in. hollow CMU with R-15.7 continuous insulation exterior (selected to represent Step 1 assembly with addition of continuous 2-in. XPS layer and strapping to support cladding)	\$21.28/ft ²	Derived from contractor's post construction cost estimates
		Step 3: 6-in. hollow CMU with R-25.4 continuous insulation exterior (selected to represent Step 2 assembly with addition of 2 nd continuous 2-in. XPS layer)	\$23.28/ft ²	Derived from contractor's post construction cost estimates
Windows	U = 0.20, solar heat gain coefficient = 0.20 (recent Wx window upgrade to triple-pane vinyl windows)	No upgrade	N/A	N/A
Basement	Uninsulated	No upgrade	N/A	N/A

Building Component	Baseline Parameter	Parameter Upgrades and Alternatives Evaluated	Cost of Upgrade	Cost Source
Refrigerator	28 units, 13,440 kWh/yr total	No upgrade	N/A	N/A
Stove	28 units, 822 therms/yr total	No upgrade	N/A	N/A
Lighting	100% fluorescent hardwired	No upgrade	N/A	N/A
Heating System	80% annual fuel utilization efficiency, gas-fired steam boiler	No upgrade	N/A	N/A
Cooling System	10 seasonal energy efficiency ratio window units	No upgrade	N/A	N/A
Ventilation	No mechanical ventilation	No upgrade	N/A	N/A
Domestic Water Heater	Standard gas-fired, energy factor 0.59	No upgrade	N/A	N/A

The above-grade wall upgrade was represented in multiple steps in the model in order to evaluate the impact of declining costs and diminishing returns for subsequent layers. As discussed previously in this report, the larger part of the expense and the majority of the nonenergy benefits are encountered in the application of the first layer of insulation and over-cladding. The first step in the wall upgrade represents the following:

- The application of the water and air control membrane at the face of the masonry
- Installation of 2 × 4 wood framing to the face of the masonry
- Installation of 1½-in. thick rigid insulating sheathing against the masonry between the 2 × 4 wood framing
- Installation of fiber cement siding.

Strapping was not included in this first step because it is conceivable that the cladding could be attached directly to the 2 × 4 wood framing. The second wall upgrade represents the measures in the first step additional measures as follows:

- Installation of continuous 2-in. thick rigid insulation
- Installation of wood strapping with long screws attached through insulation to framing.

The continuous insulation added in this step is of a thickness that would require strapping or furring for cladding attachment. While representing an appreciable expense and offering no discernible energy savings, the strapping creates a drainage cavity behind the cladding, which is important for durability of the cladding and water management.

The third step includes an additional layer of continuous 2-in. thick rigid insulation. The incremental cost represents the installation of this rigid insulation and the cost increment for longer screws needed to attach the strapping. This step was not implemented at the research project sites. However, the schematic design for the assembly that BSC prepared for CEDA's preliminary discussions with the City of Chicago Building Department included two layers of continuous rigid insulation.

An upgrade to the continuous roof insulation is included as an upgrade step to represent a comprehensive upgrade of the above-grade enclosure.

Baseline air leakage inputs represent a measurement for the two-family building and an estimate for the larger multifamily building. Section 7.3 explains how the measured air leakage reduction resulting from application of the exterior insulation and over-cladding assembly on a portion of the above-grade wall plus some other Wx measures can be taken as an approximation of air leakage reduction that would result from comprehensive treatment of the above-grade walls.

The mechanical systems and internal load component inputs are taken to represent typical conditions for these types of buildings.

7.4.2 Simulation Results

The simulation predicts that the exterior insulation and over-cladding strategy implemented in the research project would reduce heating energy use by about 47% for the two-family building and about 44% for the larger multifamily building. The simulation confirms that the relative magnitude of cooling energy use is fairly small. Predicted reductions in cooling energy use are

about 41% for the two-family building and about 39% for the larger multifamily building (Figure 55 and Figure 56). It should be noted that both buildings have cooling provided by window air-conditioning units only. Although the model simulates cooling energy use for the whole building, few of the dwelling units in the larger building actually have window air-conditioning units installed.

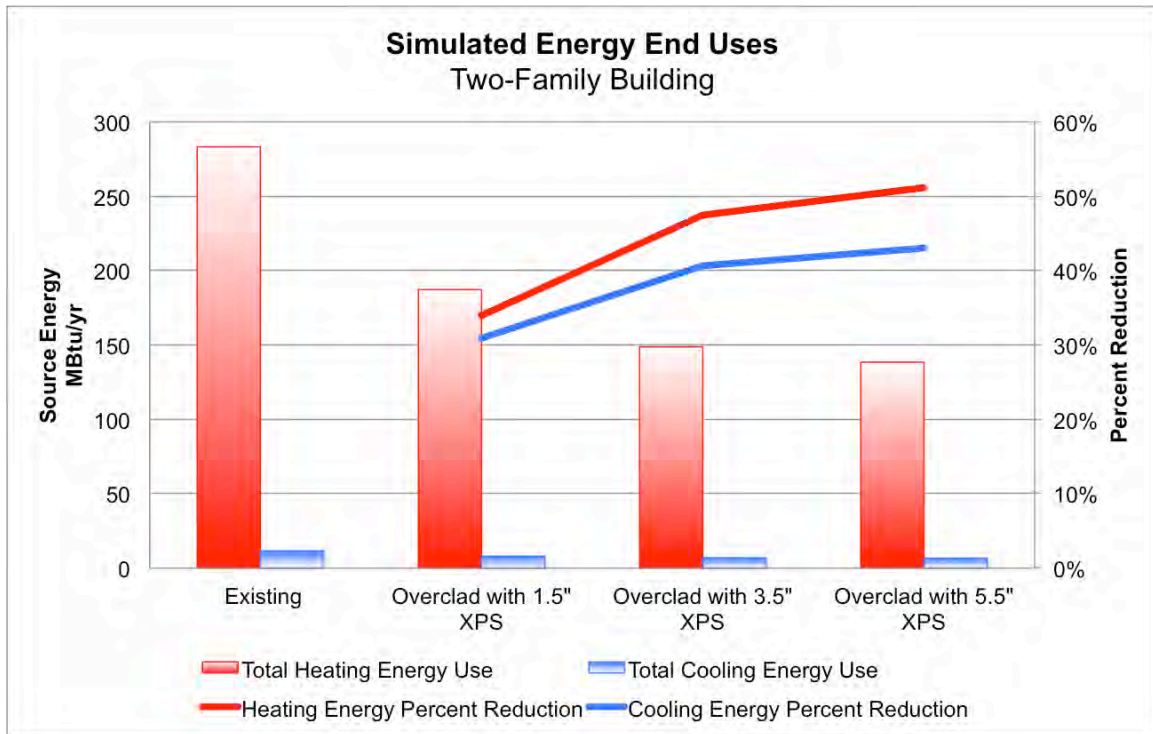


Figure 55. Predicted heating and cooling energy end uses for the two-family building

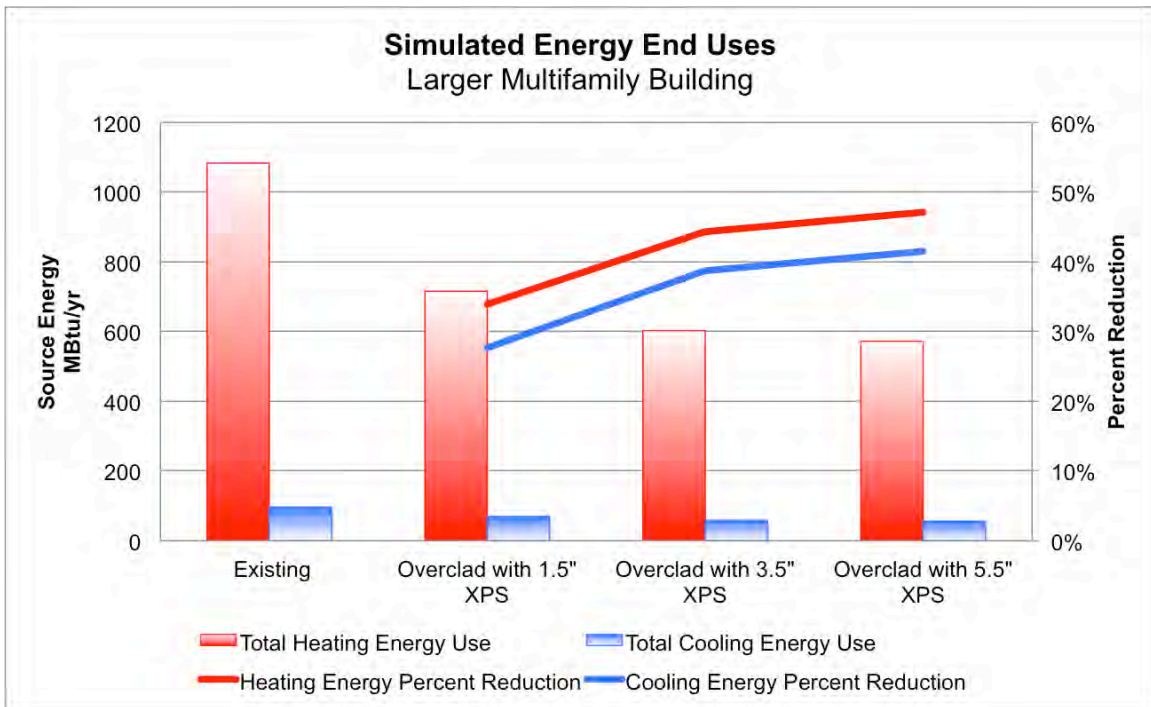


Figure 56. Predicted heating and cooling energy end use for the larger multifamily building

In the simulation, a 30% reduction in air leakage was associated with the exterior insulation and over-cladding measure. It is interesting to note that a significant portion of the predicted reductions in heating energy use result from reduced infiltration. By comparing the simulation predictions for heating energy use represented in Figure 56 with those represented in Figure 57, it is apparent that the air leakage reduction associated with the measure accounts for approximately one third of the heating energy use reduction in the case of the larger building.

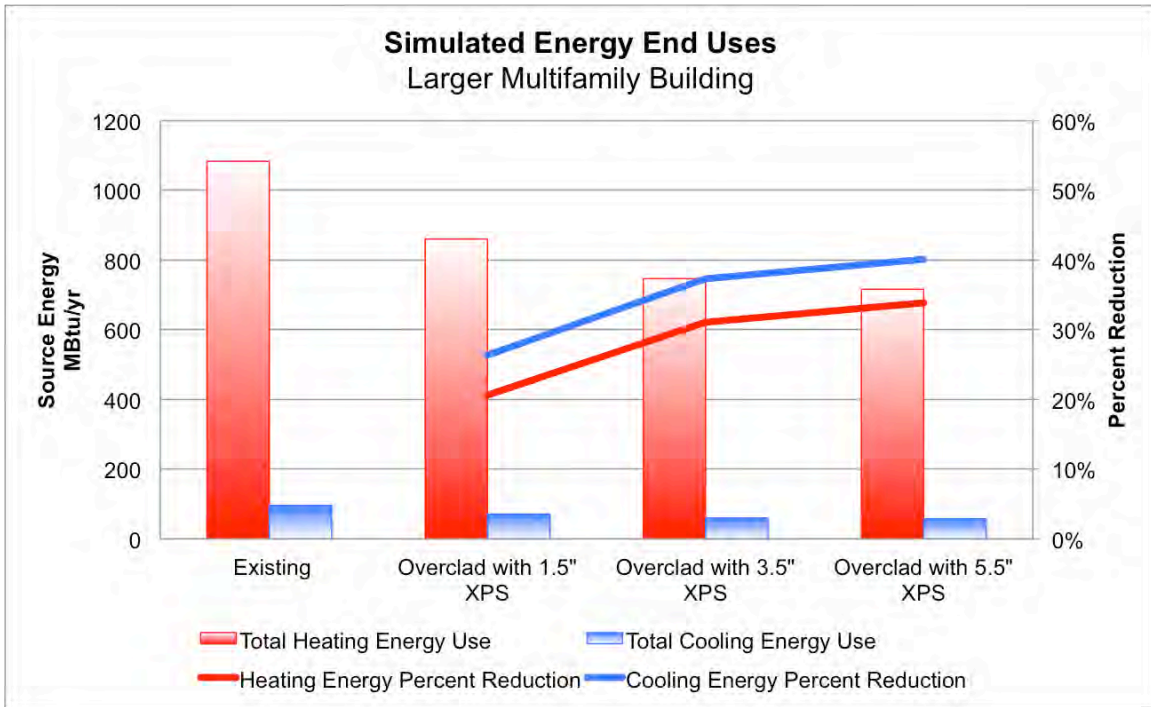


Figure 57. Predicted heating and cooling energy end use for the larger multifamily building without accounting for air leakage reduction

The charts shown in Figure 58 and Figure 59 below represent the relationship between annualized energy-related costs to total source energy savings for the building as predicted by the simulation. The annualized energy-related cost is a composite of predicted annual energy cost plus the cost of the upgrade measures amortized over a 30-year term at a 5% rate. In the charts the numbered points correspond to scenarios in the model where:

Point (1) represents the baseline case.

Point (2) represents the over-clad assembly with 1½ in. of insulation between 2 × 4 wood framing.

Point (3) represents the over-clad assembly with 1½ in. of insulation between 2 × 4 wood framing and 2 in. of continuous insulation.

Point (4) represents the over-clad assembly with 1½ in. of insulation between 2 × 4 wood framing and 4 in. of continuous insulation.

Point (5) represents the over-clad assembly with 1½ in. of insulation between 2 × 4 wood framing and 4 in. of continuous insulation, plus a roof upgraded to R-40 continuous insulation.

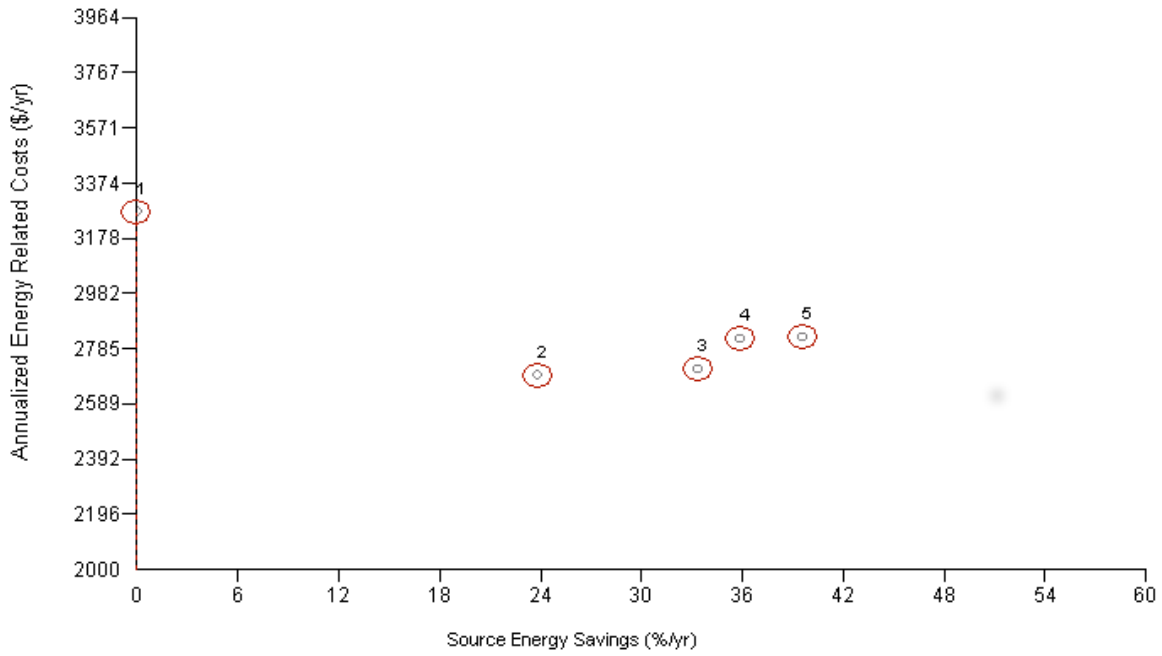


Figure 58. Predicted annualized energy-related costs and source energy savings for the two-family building under four upgrade scenarios

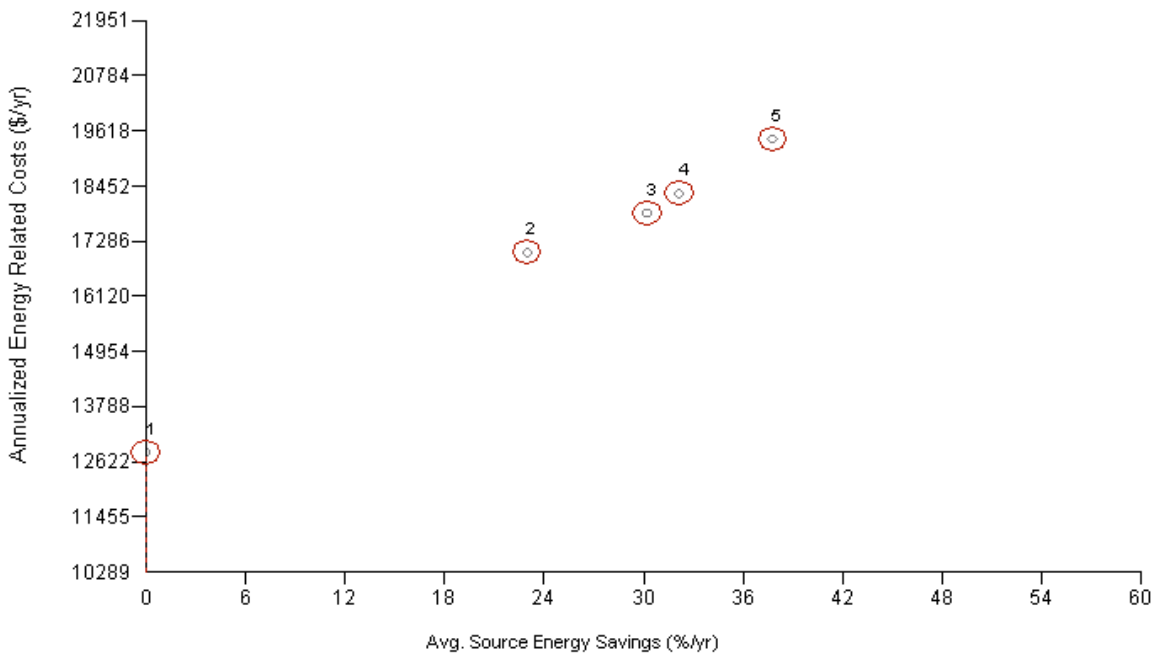


Figure 59. Predicted annualized energy-related costs and source energy savings for the larger multifamily building under four upgrade scenarios

The predicted annualized energy-related costs are lower than the baseline case for all upgrade scenarios in the simulation of the two-family building. This would suggest that the value of the energy savings benefit from the upgrade measures exceeds the amortized cost of the measure. For the larger multifamily building, the simulation predicts that each of the upgrade scenarios represents a significant increase in annualized energy-related costs. This suggests that the amortized cost of the measure exceeds the value of the energy savings benefit from the upgrade measures. The comparison of the value of energy savings relative to amortized cost of the upgrade is an expression of the cost effectiveness of the measure *with respect to energy savings* or *energy savings cost effectiveness* of the measure.

This energy savings cost effectiveness difference observed between the two-family and larger multifamily building results from a significant difference in costs for the upgrade measures. As discussed above in Section 7.2, the building height and access conditions have a significant impact on the unit cost of the exterior insulation and over-cladding measure. One can deduce that with constrained access and building height above two stories, the amortized cost of the insulation and over-cladding assembly exceeds the value of the energy savings.

Energy savings cost effectiveness is not an adequate expression of general or overall cost effectiveness, because it does not include recognition of values beyond energy savings that might be represented in the measure. For example, the primary or most valued benefit from a building owner's perspective might be one of aesthetic improvement or increased durability with respect to moisture risks.

The exterior insulation and over-cladding assembly studied in this research provides significant benefits that are not represented in energy costs. While it may not be possible to quantify the value of these nonenergy benefits, it is possible to identify components within the assembly that do not provide energy savings benefits but that do provide a significant portion of the nonenergy benefits. As discussed in Section 7.2, when the cost for these components are subtracted from the overall measure costs, the analysis can compare the value of energy savings to costs that are more nearly (but not perfectly) associated with the energy benefits.

Section 7.2 compared the relative nonenergy benefits of a noninsulated over-cladding assembly to those of the exterior insulation and over-cladding assembly (Table 2). This comparison presumes it is conceivable that a building owner might over-clad a masonry building without adding insulation in order to achieve the nonenergy benefits associated with this approach. While the noninsulated over-cladding assembly did not offer exactly the same level of nonenergy benefits, the nonenergy benefits are, at least, similar. The difference in energy performance benefits between the insulated and noninsulated over-cladding assemblies is more or less equivalent to the net energy benefits of the insulated over-cladding assembly. Therefore, subtracting the cost of the noninsulated over-cladding from that of the insulated over-cladding measures yields a net energy-related measure cost that can be associated with net energy benefits.

Figure 60 and Figure 61 below are similar to Figure 58 and Figure 59 with an important difference: the amortized measure cost represents only the cost increment between the estimated cost of the noninsulated over-cladding assembly and that of the insulated over-cladding alternatives.

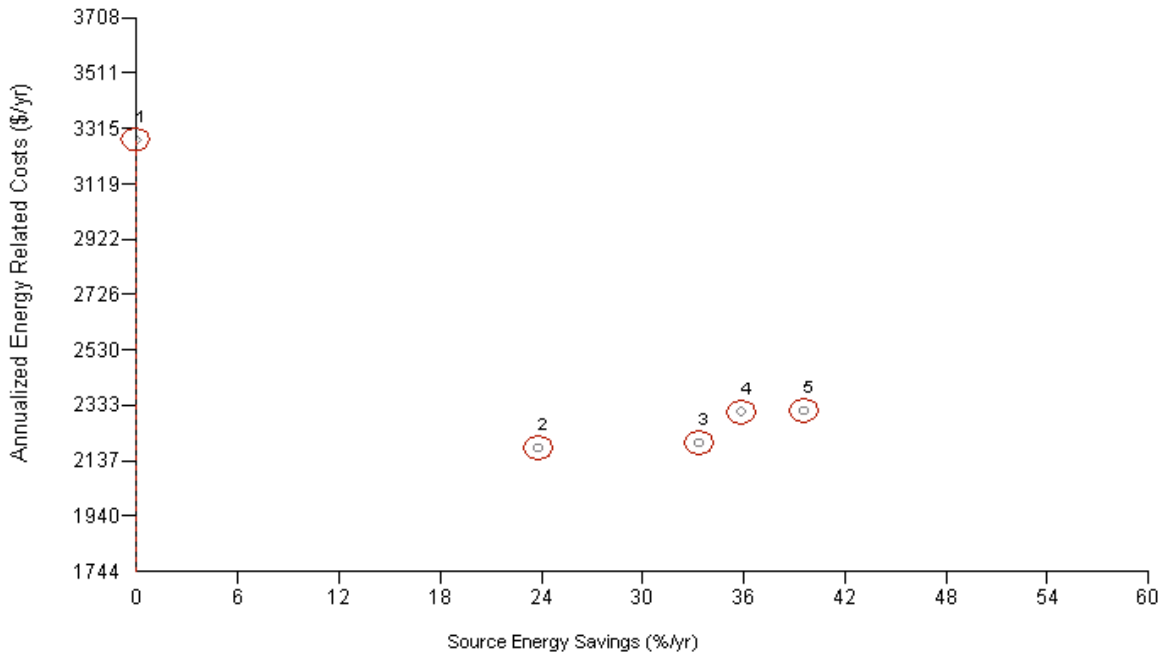


Figure 60. Predicted annualized energy-related costs and source energy savings for the two-family building under four upgrade scenarios using net energy-related measure costs

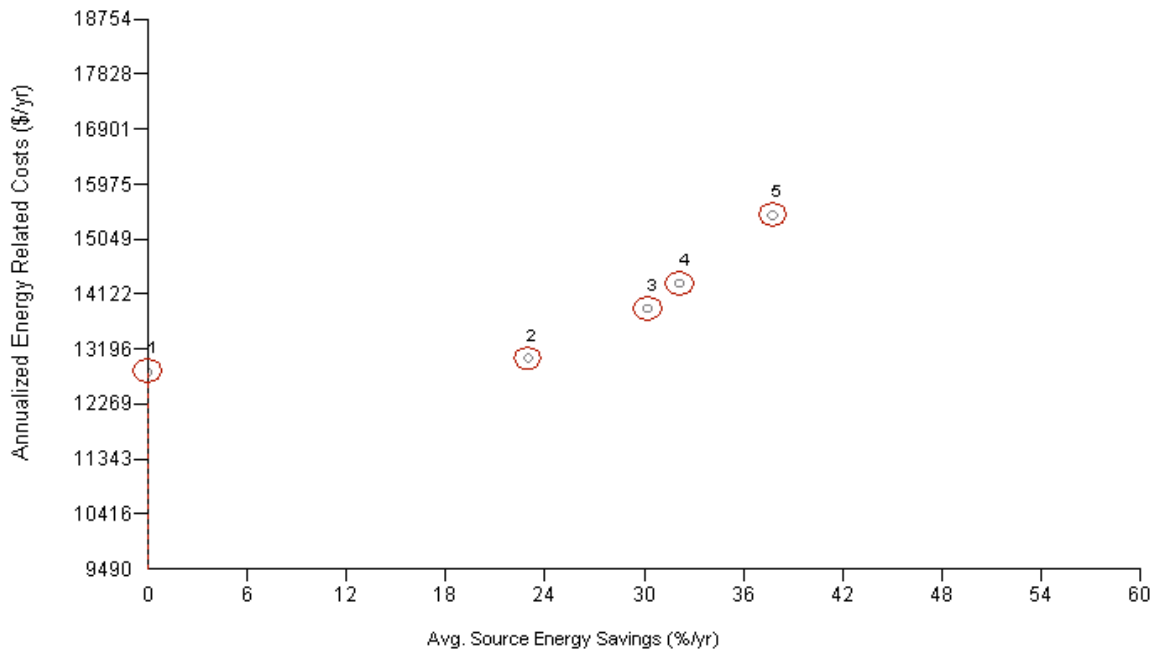


Figure 61. Predicted annualized energy-related costs and source energy savings for the larger multifamily building under four upgrade scenarios using net energy-related measure costs

As might be expected, the simulation results for the two-family building show a stronger reduction in annualized energy-related costs for the exterior insulation and over-cladding measures when the cost of the noninsulated over-cladding is subtracted from the upgrade measure costs. For the larger multifamily building, the simulation still predicts an increase in annualized energy-related costs with each of the upgrade scenarios. However, the first insulated over-cladding scenario has a relatively small impact on annualized energy-related costs.

This comparison is somewhat contrived because, in reality, one would not install the exterior insulation without the nonenergy-related components. On the other hand, it is conceivable that the over-cladding would be installed without insulation.

8 Conclusions

The observations and collected data from just two implementations of the exterior insulation and over-cladding approach provide valuable lessons and insights. These lessons and insights provide answers to questions pertinent to broader adoption of the approach.

8.1 Under what conditions or for which common building situation is the strategy recommended?

The approach demonstrated through the research projects provides a unique solution for certain situations where opportunities are otherwise nonexistent. Some of the benefits of the approach depend upon the circumstances of the building. Conditions of access can render the strategy more or less costly and may impact whether the strategy is appropriate for a particular building.

The strategy is recommended where the following circumstances apply:

- Noninsulated masonry bearing-wall construction
- Exterior wall does not provide satisfactory performance in terms of comfort, energy use and/or water management
- Occupied building where retrofit activities must minimize disturbances to the interior
- The masonry exterior is not regarded as providing a significant positive contribution to the character or aesthetics of the building.

The following factors tend to favor application of the exterior insulation and over-cladding strategy:

- Building has ample working area around the base.
- Building has fewer than three stories.
- There is appreciable (and appreciated) ongoing expense to maintain the masonry.

The following factors tend to complicate application of the exterior insulation and over-cladding strategy:

- Building has restricted working area around the base.
- Building has three stories or more.
- Fire escape or deck that cannot be independently supported is attached to the building.
- Need for significant repairs to the masonry.

The application of the exterior insulation and over-cladding strategy is not recommended in the following conditions:

- Highly articulated and/or high quality brick that contributes to a façade that is an important positive benefit to the character or aesthetics of the building
- Constrained access that cannot support work on the exterior of the building.

For typical Chicago brick masonry buildings, the strategy would not be recommended for the street elevation. The exterior insulation and over-cladding is more likely to be suitable for the side and rear elevations.

8.2 What are the significant challenges to implementation?

Significant challenges to implementation of the exterior insulation and over-cladding strategy include:

- Cost
- Working access
- Obstructions on the wall surface
- Irregularities in existing construction
- Aesthetic coordination.

Despite indications that the strategy can be cost effective in either a broad or an energy cost-specific sense, the significant expenditure is likely to present a barrier to wider adoption. The simulation analysis shows that the strategy can reduce annualized energy-related costs for smaller buildings. In the case of the studied larger building, for which the unit installation costs were considerably higher, the simulation did not show a reduction in annualized energy-related costs. However, sophisticated owners of larger buildings are also more likely to value the nonenergy benefits of, for example, reduced maintenance cost, improved resident comfort, and elimination of freeze-thaw risk. Given the significant initial outlay represented by the strategy along with the durability of the energy and nonenergy benefits, the strategy may prove a good candidate for special financing programs such as on-bill financing or low-interest loans that reduce the required initial outlay on the part of the building owner.

As noted several times in this report, the cost of implementation is significantly influenced by the working access to the building, as well as the general conditions of the site in terms of criteria such as perceived security. While constrained access and concerns for security of the site can make the implementation prohibitively expensive, there are also likely to be situations where very small distances between adjacent buildings render any work to the exterior of the building practically impossible.

Major obstructions include decks, stairs, and fire escapes supported by the masonry wall. If the obstruction cannot accommodate the thickness of the exterior insulation plus cladding and the obstruction cannot be moved (for cost or feasibility reasons), the obstruction may preclude the exterior insulation and cladding strategy for that section of wall.

Minor obstructions include elements such as gutters, conduits, and satellite dishes. Performance of the system is compromised if these are left in place. These obstructions should be removed from the wall to be treated prior to application of the water and air control membrane.

It is common for masonry walls of older buildings to exhibit spalling or other flaws in the bricks and to be out of plumb, not true, and/or not straight. A first order of concern with such irregularities is to ensure that the structure is fundamentally sound. Provided these irregularities do not present concerns for structural stability, challenges may remain for implementation of an exterior insulation and over-cladding assembly. The over-cladding assembly may also be viewed

as an opportunity to address irregularities in the wall, such as demonstrated at the larger research project where the contractor was able to provide a flat and true cladding surface over a wall that was significantly out of plumb toward the top.

Other common irregularities or idiosyncrasies of a building that would affect implementation of an exterior insulation and over-cladding assembly include inconsistent dimensional relationships between windows and window openings (as exhibited at both research project sites) and inconsistent slopes and profiles of existing sills (as exhibited at the two-family building). These factors require some flexibility in the details affected by these inconsistent existing building elements. Still, in some cases, it may be difficult to anticipate inconsistencies. Inconsistencies discovered during construction may render design details infeasible (e.g., materials do not fit) or nonperforming (e.g., materials block weep holes).

Particularly if using large panel cladding, it can be challenging to provide an installation of cladding that coordinates aesthetically in terms of, for example, cladding joints aligning with building elements. In order to ensure that the over-cladding assembly contributes to the appearance of the building, it is useful to have the layout of the cladding deliberately designed. It is likely that aesthetic coordination will result in designs that do not use the materials exclusively in the factory-supplied dimensions. This will likely increase both material and labor costs. On the other hand, if the over-cladding is seen as detracting from the appearance of the building, it is less likely to gain wider adoption.

8.3 What level of airflow control improvement can be expected with the strategy?

For the building where the air leakage for the entire building was measured both before and after the retrofit, it was found that a 30% reduction in air leakage measurement could be achieved through the exterior insulation and over-cladding strategy in combination with some Wx measures. For the particular low-sloped roof building that was the subject of this research, it is likely that the majority of the air leakage reduction from attic air sealing measures would be subsumed by comprehensive treatment of the exterior wall system (i.e., all four sides). Therefore, it is predicted that an air leakage reduction of greater than 30% would be achieved through comprehensive treatment of the above-grade walls of this building.

Clearly, the configuration of the building was a significant factor in the overall air leakage reduction achieved in the study project. While measurement of a single building does not permit prediction of specific performance improvements for other buildings, it is reasonable to suggest that, for buildings with a low-sloped membrane roof in good condition, the exterior insulation and over-cladding approach would be likely to result in very significant reductions in the buildings overall air leakage.

For buildings with a steep-sloped roof or nonmembrane roof, the air leakage performance is expected to be highly dependent on the airflow control of the attic floor or roof (see Neuhauser 2012). The exterior insulation and over-cladding would be expected to bring significant reductions in overall air leakage only where the attic floor plane or roof already offers relatively robust airflow control. In such cases, the exterior wall measure is well positioned to address a significant portion of the remaining air leakage for the building.

8.4 What risks inherent in implementation of the strategy must be addressed?

Inherent risks introduced by the system are limited. It is possible that the reduction in outward drying would be perceived as a risk and that this perception would create barriers to implementation. The use of foam plastic insulation in the assembly presents risks that are managed by proper implementation. Both the perceived risk of limited outward drying and the real and manageable risks associated with foam plastic insulation are discussed below.

8.4.1 Limited Outward Drying

The exterior insulation and over-cladding approach reduces risks to the building. Because the assembly protects the masonry structure from incident rainwater through multiple layers of control, the most significant risks to the durability of the structure are removed. Providing a significant amount of thermal resistance to the exterior of the masonry assembly maintains the masonry within a very stable thermal environment. This removes structural stresses that otherwise result from thermal cycling. Throughout much of the year in a heating climate, masonry behind the exterior insulation and over-cladding will also be significantly warmer than noninsulated or interior-insulated masonry. Because the brick masonry is warmer, it will have higher *inward* drying capacity and also have greater capacity to safely store moisture. In essence, the wall is much less likely to get wet and even if it does get wet, it is much less vulnerable to damage resulting from wetting due to an increased ability to dry inward and an increased capacity to safely store moisture.

The exterior insulation and over-cladding assembly limits drying to the exterior. The water and air control membrane and rigid board insulation applied over the face of the brick masonry will essentially prevent evaporation and convective transfer of moisture from the masonry to the exterior. The layers of rigid board insulation within the exterior insulation and over-clad assembly significantly impede vapor diffusion through the assembly. However, this limited drying does not represent an inherent risk relative to leaks through or in the existing enclosure, nor does it represent an inherent risk relative to moisture within the exterior retrofit assembly as a result of the simultaneous increase in inward drying and increased capacity for moisture storage.

Because the exterior insulation and over-cladding assembly protects the existing masonry from incident rainwater, the likelihood of leakage from the exterior through the masonry is greatly reduced. Proper design and implementation of the exterior insulation and over-cladding assembly control rainwater such that it is drained and directed away from the existing wall. In both of the exterior insulation and over-cladding projects included in this study, the existing windows remained in place. There was no evidence that these windows had been installed in a drained opening. Without a pan flashing beneath the window, water that passes through the window unit or through or around the window frame will leak into the wall or into the interior. The thickness of the exterior insulation and over-cladding shield the opening and thereby significantly reduce incident rainwater reaching the opening. The generally warmer masonry has increased capacity to both store water and dry to the interior. Therefore, even with limited to no drying to the exterior, the exterior insulation and over-cladding strategy decreases the risk that leakage through openings leads to accumulation of moisture.

The exterior insulation and over-cladding assembly implemented through this research project is designed to control water at the face of the existing masonry (with the adhered water and air

control membrane), at the exterior face of the insulating sheathing (behind the drainage cavity), and at the face of the cladding. Despite the fact that the assembly may include impermeable insulation materials and that these materials are installed in continuous layers, there remains space for drainage and limited drying in the gaps between individual pieces and in the three-dimensional airflow networks that these gaps create. The wood framing installed against the masonry and the wood strapping over the face of the exterior insulating sheathing represent moisture-sensitive materials within the assembly. By design, these moisture sensitive materials are installed in a vertical orientation only in order to facilitate drainage of liquid water by gravity.

We have found in the course of this study and in other experience that contractors are, at least initially, resistant to the concept of installing furring and strapping in a vertical orientation only. This is a risk associated with implementation but not inherent in the system itself. When framing against the masonry or strapping in the drainage cavity is installed in a horizontal position, drainage is impeded and there is increased risk that water will dwell longer within the system and upon moisture-sensitive materials. Strapping in the drainage cavity would be able to dry by diffusion into the drainage cavity. Drying of moisture collecting on strapping in the drainage cavity may be aided by ventilation of this cavity. Both in the case of the horizontal strapping in the drainage cavity and horizontal framing against the masonry, it cannot be assured that the drying potential available would be able to balance the accumulation of moisture caused by the horizontal orientation. However, there is sufficient redundancy within the over-cladding assembly that localized decay at isolated horizontal wood members will not jeopardize the system.

The changed moisture dynamics associated with limited outward drying through the exterior insulation and over-cladding assembly are addressed by the following measures:

- Flash openings to drain to the exterior, OR, if openings cannot be flashed, protect the primary sealant joints and provide a means to replace or repair the element in the opening without disrupting the surrounding assembly.
- Provide flashing above openings with a drip edge or kick-out at the outer face of the assembly.
- Investigate the building for any existing water leakage issues. Remediate the issues before implementation of exterior insulation and over-cladding.
- Promote drainage from and within the assembly. Avoid elements that might impede drainage such as horizontal framing or strapping.
- Provide ventilation within the building to manage residual exterior generated or interior generated moisture.

8.4.2 Foam Plastic Insulation

Solid brick masonry assemblies offer superior resistance to combustion. Solid masonry assemblies tend not to provide habitat for vertebrate pests. The exterior insulation and over-cladding assembly introduces risks in that:

- Foam plastic insulation is a combustible material.
- The foam plastic insulation as well as the drainage cavity behind the cladding has the potential to provide habitat for pests.

These risks are managed by the following measures:

- Cover the exterior insulating sheathing with noncombustible cladding.
- Provide screening for openings to the drainage and ventilation cavity between the cladding and the exterior insulating sheathing.
- Provide protection for edges of insulation not covered by the cladding, such as at the base of the wall or at vertical transitions.

8.5 What are the recommended practices critical to achieving performance?

Observation of implementations of the exterior insulation and over-cladding approach inform both general and specific recommendations relative to the performance objectives of the assembly.

8.5.1 General Recommended Practice

Upon observation of the construction process, it was evident that the crews for each of the two projects were competent and resourceful. Still, errors occurred that resulted either in the need to correct implemented work or in compromises to the performance of the assembly. Most of these errors can be traced to a lack of understanding of the functional intent of the design element implemented (or not implemented). For example, a lack of appreciation for the intended continuity of airflow control at the parapet led to:

- Installation of a transition membrane at the parapet that did not transition the airflow control (Figure 30)
- Sequence of wood framing installation that precluded transition of airflow control (Figure 27).

A lack of appreciation for the drainage functions of the water and air control membrane and of the drainage cavity behind the cladding appears to have been a factor in:

- Details implemented in a way that concentrates moisture at openings (Figure 45)
- Installation of framing against the masonry and (initially at one site) strapping in a horizontal orientation (Figure 19, Figure 21, and Figure 25).

The fact that the contractors did not appreciate the need for a continuous water and air control at the face of the masonry or the need to ensure effective transition of these control functions is likely to have contributed to:

- Sequencing that precluded continuity of the control function around windows (Figure 14)
- The presence of gaps in the water and air control membrane at window openings (Figure 16 and Figure 17).

A misunderstanding of the risks intended to be managed by the screening at the base of the wall assembly led to:

- Sequencing that precluded effective protection at base of assembly (Figure 32)
- Screening installed at the base of the assembly that fails to protect the exposed edge of the insulating sheathing (Figure 62).



Figure 62. Screening at the base of the wall that fails to protect the exposed edge of the insulating sheathing near grade
(Credit: Scott Sanders, CEDA)

After completing substantial portions of the construction, both contractors were asked about potential cost savings that might be realized in future applications of the exterior insulation and over-cladding approach. Both suggested that eliminating the elastomeric paint layer would result in substantial cost savings. This demonstrates that, even after having implemented substantial portions of the exterior retrofit, the contractors did not appreciate the need for airflow and water control at the face of the masonry.

In order to engage the skill and resourcefulness of the contractors and crews in fulfillment of the design intentions, it is necessary to establish an understanding of the functional design intentions.

A three-part process is proposed for establishing understanding of the functional design intent:

1. The functional intent of elements within an assembly or detail should be explicitly noted in construction drawings.
2. The designer and contractor should review the rationale for the functional intent (e.g., water control) called out in the drawings. This will serve to develop an appreciation for the need for various functions in the design (e.g., airflow control, pest control) and tap the resourcefulness of the contractor, who might be able to suggest alternative methods for meeting the same intent.

3. The construction contract and schedule should allow for in-situ mockups of critical details. In-situ mockups are valuable in communicating functional requirements to crews and provide an opportunity to evaluate whether conditions of the building require refinements to details in order to achieve the functional intent. Mockups are also extremely valuable in providing contractors and crews the opportunity to develop confidence with unfamiliar systems or approaches.

8.5.2 Specific Practice Recommendations

The experience of the two implementations of the exterior insulation and over-cladding strategy yields specific recommendations that would benefit contractors involved in future implementations of the strategy.

- Remove any obstructions that can be removed from the wall surface prior to application of the water and air control membrane at the face of the masonry. It is best to apply the water and air control membrane at the field of the wall in one uninterrupted step so that subsequent steps do not inhibit continuity of the control membrane.
- When installing the water and airflow control membrane at the face of the masonry, treat penetration, opening, and obstruction details separately from the field of the wall. This allows for greater attention to areas that require it and allows for application in the field of the wall to proceed more rapidly. It is worth noting that details around penetrations, openings, and obstructions and may require different materials and methods than the field of the wall.
- Because the need to terminate self-adhered peel-and-stick type flashings is not well understood or received, consider using liquid-applied flashing at critical details.
- Ensure the trim returns slope away from openings and that the trim returns above openings include a provision for drainage.
- Ensure that flashing is properly lapped and slopes away from the building.
- Avoid installation of framing against the masonry or strapping over the insulating sheathing in a horizontal orientation.
- Anticipate imperfections or “character” in the masonry walls of older buildings. The exterior insulation and over-cladding assembly should be able to conform to wall surfaces that are slightly out of flat. More noticeable imperfections at the masonry can be flattened by the use of sloped insulation boards or thickened strapping carefully scribed and re-sawn to provide a flat attachment surface for cladding. Methods used to address imperfections in the wall should avoid creating large air gaps in the insulation layer.
- Plan remediation of the parapet. Experience and observation have shown that many parapets are commonly not in good repair. It may be possible to use over-cladding as a means to re-establish the parapet height if the masonry is deteriorated at the top.
- Anticipate variability of existing building dimensions by providing insulation material at various thicknesses for critical details such as window surrounds.

- Plan to provide protection for the base of the assembly. Attach screening to the base of the existing masonry wall before installing wood framing and insulating sheathing. Or, use a closure piece that permits drainage, slopes toward the front of the wall, provides ventilation openings, and is bedded in sealant against the existing masonry.
- If using large-sized panel cladding (as distinct from lapped cladding), design and plan joints to coordinate with building elements. Consider designed joints, reveals, or battens.
- Provisionally attach insulating sheathing with screws and washers to allow continuous taping of seams.
- Use a starter strip of insulating sheathing at the base of the wall to provide an offset of 12 in. or more between horizontal joints.

8.6 What are successful strategies to integrate windows into a masonry wall insulation and cladding retrofit system?

At window openings, it is critical to provide robust water control and effective transition of both the airflow and thermal control to the window unit.

In the ideal retrofit circumstances, windows would be removed to allow flashing of the window opening. Proper flashing of the window opening would include a pan flashing to direct water leaking through or around the window back out over the cladding or to the drainage cavity behind the cladding. The sill pan flashing as well as flashing at jambs of the window opening would be integrated with the air control membrane at the face of the masonry. These jamb and sill flashings would then double as transition membranes for the airflow control. A dedicated airflow control transition membrane would be needed at the head of the window to transition the airflow control into the window opening. With the airflow control transitioned into the window opening, the window is then sealed to these transition membranes around the inside perimeter of the window frame to connect the window in an airtight manner to the airflow control of the wall system. Joints at the head and jamb of the window would be sealed at the outer face of the window frame to prevent water entry, whereas the joint between the bottom of the window frame and the sill flashing would be left open or provided with weeps to allow drainage.

Notwithstanding the ideal nature of this flashed window opening scenario, many retrofit situations, including the two projects evaluated in this study, present a different reality wherein the existing windows are to remain in place. Retaining the existing windows presents some challenges to providing effective water control and airflow control at the window openings.

Where the windows are not provided with pan flashing beneath them, the approach for integrating the window with the water control function of the wall system is essentially a face-sealing approach. In this approach, the water control membrane of the wall system is brought to and seals to the face of the window frame on all four sides. Care must be exercised not to cover any weep holes in the window frame. This approach establishes the water control at the face of the window unit and provides for drainage through weep holes in the window frame of small amounts of water that might leak between the sash and the window frame. This approach does not have provisions to directly manage water that leaks through or around the window frame. The face-sealed approach to water control at window openings relies upon either or both of the following conditions:

- Windows do not leak.
- Where windows do leak, they leak to where the wall system can safely store and manage the amount of water leaking.

Brick masonry wall assemblies may have some capacity to safely store water. However, the exterior insulation and over-cladding strategy will virtually eliminate the ability of the masonry to dry to the outside. Thus, the balance between safe storage capacity and drying could be disrupted by application of the exterior retrofit assembly.

The strategy to manage risks of an existing face-sealed window includes directing water away from the window opening as much as possible, protecting joints between the window frame and surrounding assemblies, and finally, providing details that facilitate removal of the existing window for repair or replacement.

The membrane applied to the face of the masonry is the primary water and air control layer for the system. Both functions are performed by the same material as it wraps into openings and seals to the window frame. Because the details around a window opening create many corners, gaps, and irregular surfaces, the area around a window requires a more robust water and air control membrane than is applied in the field of the wall. For example, an elastomeric paint might be recommended as the water and air control membrane for the field of the wall, but a liquid-applied flashing would be more appropriate for window openings (and other challenging details). Unlike sheet membranes, liquid-applied membranes conform well to inside corners, thus avoiding gaps in the airflow control function. Liquid-applied membranes will require substrate support to bridge small gaps and cracks.

A sheet flashing will be needed to extend over the insulating sheathing of the wall and direct water out over the face of the cladding or to the drainage cavity behind the cladding. The top edge of the sheet flashing (at sill and jambs) must be integrated with the air/water control membrane in the window opening.⁹

When the window opening is prepared in this way, subsequent reinstallation or replacement of the window could provide flashing for a drained opening (as described in Section 6) that readily integrates with the water and airflow control established for the face-sealed window.

Because masonry is generally highly conductive, it is important to insulate the returns at the window opening. The thickness of the insulation should be maximize to the extent practical while not obstructing view, inhibiting operation of the window, or causing the weep holes of the frame to be below the sill trim. Coil stock trim returns allow a greater thickness of insulation to be accommodated at the window opening returns. The thickness of insulation that can be accommodated at the window opening may not be consistent across all window openings of the building. The implementation should aim to achieve at least R-5 continuous insulation over the window returns.

In order to protect the water and airflow control joint at surrounding the window frame, the insulation returns and trim should butt into the window frame with a sealant joint between the trim returns and window frame. Because the head return trim intercepts water draining from

⁹ This same approach to the flashing at the sill and base of the jambs would be employed in cases where the existing window opening did include a sill pan flashing.

above the window, it must be sloped to the outside (away from the window) and have provision to drain water at the front edge. If the window sill does not offer a positive slope to the outside or if the slope is weak, the sill trim should be shimmed to provide an adequate slope to direct water at the face of the cladding and trim away from the window.

In summary, the recommended strategies for integrating windows into a masonry wall insulation and cladding retrofit system are:

- Use a robust water and air control membrane such as a liquid applied flashing, at window openings.
- Apply water and air control at window openings separately from the water/air control membrane on the wall to permit attention to detail at window openings and rapid application in the field of the wall.
- Extend the water and air control membrane onto the window frame and seal to the window frame, but ensure that weep holes in the window frame are not obstructed by the water and air control membrane. The weep holes for the window frame should also be above the sill trim.
- Use a sheet membrane to extend the window sill flashing out over the face of the cladding or to the drainage cavity behind the cladding. Integrate the top edge of the sheet flashing with the water and air control membrane at the sill and jambs in an air/watertight flexible and durable manner.
- Insulate the returns of the window opening to a minimum of R-5. Provide insulation material at various thicknesses to accommodate variations between windows.
- Use coil stock trim returns to maximize the thickness of insulation that can be accommodated at window returns.
- Protect the joint between the window frame and the surrounding material/assembly by butting the insulation and trim returns into the window frame. Seal the trim to the window frame.
- Ensure that the head trim return slopes away from the window opening and has drainage holes at the front edge (away from the window).
- Where the slope of existing sill is weak, shim sill the trim to provide adequate slope away from the window.
- Install removable casing trim around window openings to allow future work on the window openings without requiring removal of—or causing damage to—cladding surrounding the window.

9 Looking Forward

9.1 Gaps

Observations and analysis conducted through the course of this research identified several development gaps that impact the feasibility of providing high performance exterior insulation and over-cladding. These are outlined below.

9.1.1 Costs

Even with the implemented strategy representing a significant decrease in annualized energy-related costs, the significant financial outlay required to implement the strategy is likely to represent a barrier to both homeowners and energy efficiency programs. The cost for the measures may decrease if contractors become more familiar with the measure. The process for implementation of the strategy at the larger building provides an indication that costs would decline after further iteration of the strategy by contractors. The contractor for this building completed the treatment of one wall of the building in approximately three weeks.

Implementation at the second wall of the building (which was essentially the same size as the first) took this contractor less than one week.

9.1.2 Aesthetic Coordination

The over-cladding of a building has the potential to improve the appearance of the building. Over-cladding might even be employed to produce a creative visual expression of the building. Greater attention to the appearance of the insulation and over-cladding assembly is likely to increase the appeal of the approach. The increased appreciation for the aesthetic benefits of the exterior insulation and over-cladding can then be leveraged to promote broader adoption.

9.1.3 Assembly Approvals Relative to Fire Safety

Even when the existing building is of solid masonry construction, an exterior insulation and over-cladding assembly might attract concerns relative to fire safety. The expense of testing specific exterior insulation and over-cladding assemblies would almost certainly preclude implementation of these assemblies. Industry-accepted protocols for evaluating “equivalent risk” relative to fire safety (see Kuhn and Jeffrey 2012) would make it possible to develop and implement strategies adapted to individual buildings.

9.1.4 Product Availability

Another avenue to address the potential for fire safety concerns would be to use assemblies based on products that avoid fire safety concerns. An EIFS that uses mineral wool insulation rather than XPS would resolve one of the significant barriers to using EIFS systems for enclosure retrofit. At this time, mineral wool-based EIFS systems are not readily available in the United States.

9.1.5 Appreciation for Maintenance

The exterior insulation and over-cladding strategy studied in this research project has the potential to significantly reduce maintenance needs for masonry buildings. Where there is a general lack of appreciation for maintenance or for the need for building maintenance, there is little value represented in avoided maintenance.

9.2 Directions for Further Research

The current research project studied a particular strategy for retrofit of solid masonry structures within a fairly specific implementation context. Related strategies that merit further research include:

- Exterior insulation and over-cladding assemblies employing closed-cell spray-applied insulation
- Exterior insulation and finish systems employing noncombustible insulation material.

Important details of exterior insulation and over-cladding that could be studied in other project contexts include:

- Connections between exterior insulation and over-cladding assemblies and sloped roofs
- Implementation of exterior insulation and over-cladding assemblies around attached obstructions such as fire escapes and decks supported on the masonry wall.

Measured performance could provide a more certain demonstration of the strategy's impact on building performance. Monitoring of energy use at each of these buildings would contribute toward this end. Other measurements would benefit from controlled and comprehensive implementations:

- Thoroughly measure air leakage performance before and after implementation of the exterior insulation and over-cladding strategy and in the absence of other measures that might impact air leakage performance.
- Record energy use data for an extended period before and after implementation of the exterior insulation and over-cladding strategy and in the absence of other measures that might impact energy use.

As suggested above, additional iterations of the approach studied may reduce the measure cost. Studying a broader test implementation involving multiple implementations by contractors would provide an opportunity to project more mature market costs and persistent implementation challenges to the measure.

Quantification of parameters related to nonenergy benefits such as, for example, improved comfort, could lead to increased perceptions of overall value represented by the exterior insulation and over-cladding approach.

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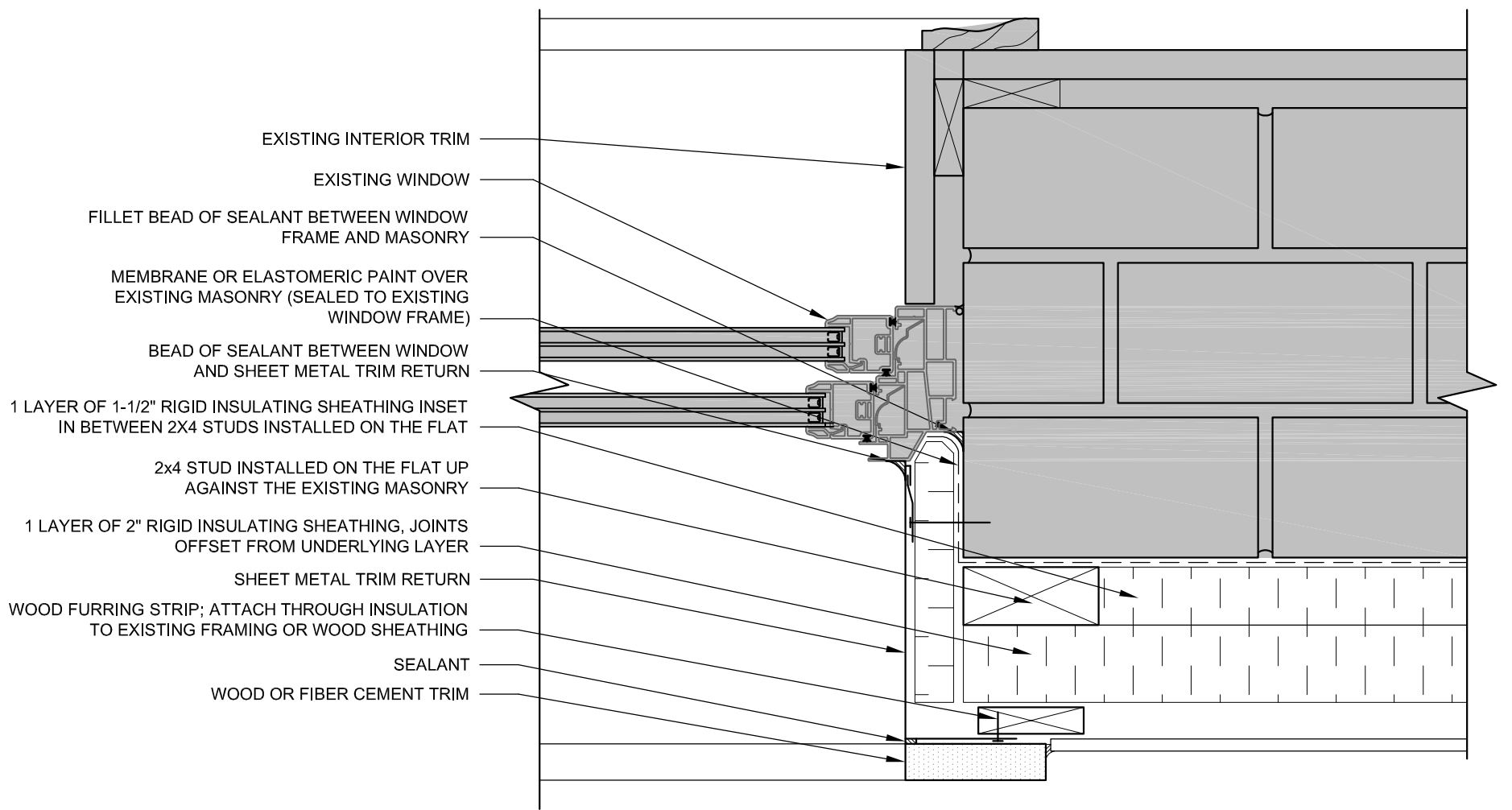
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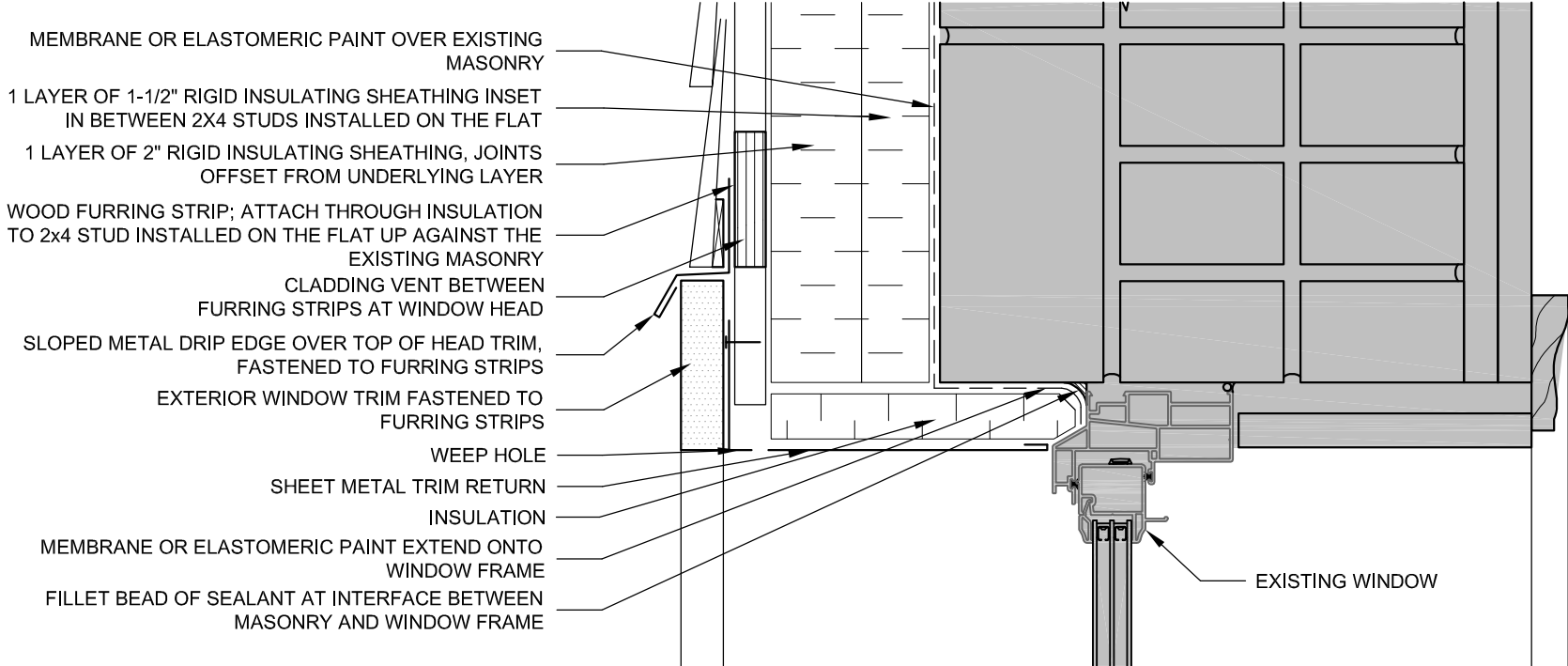
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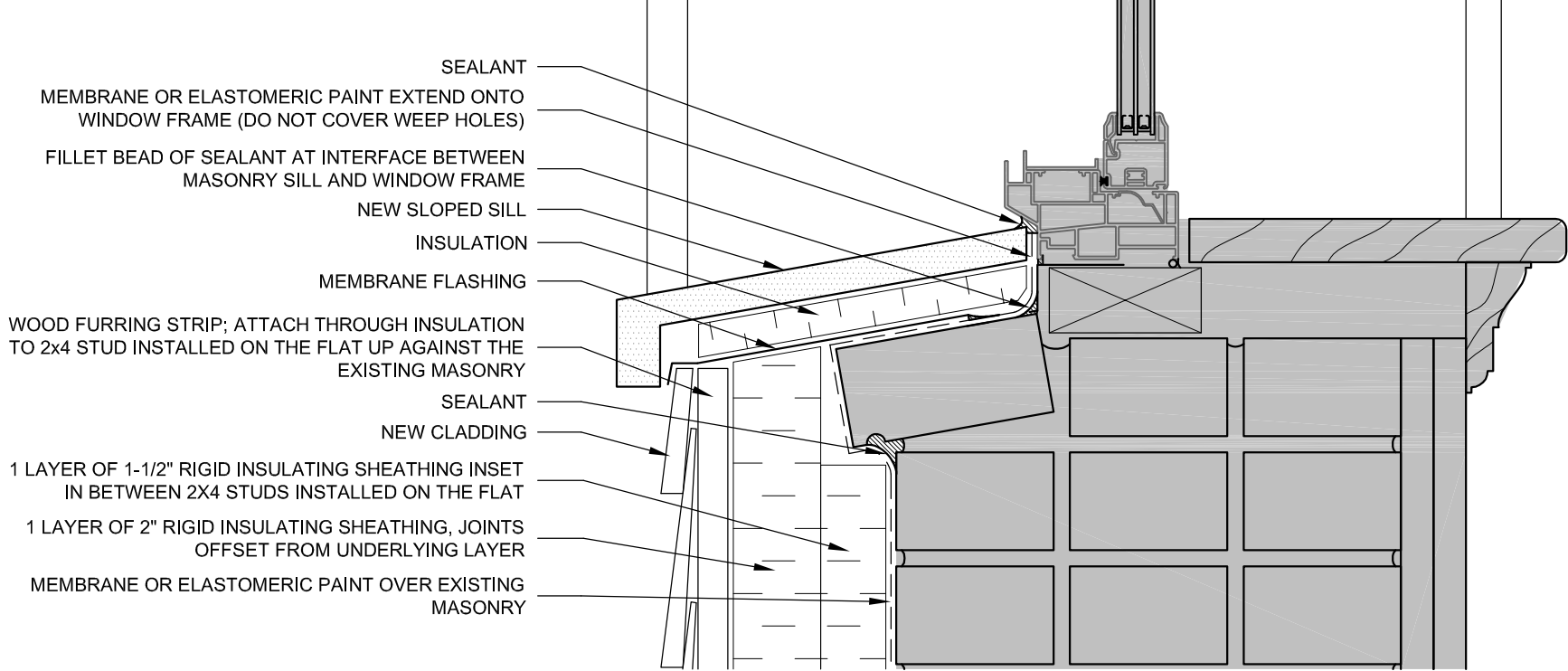
Appendix A: Schematic Details Incorporated Into Contractor Bid Packages



3 EXISTING REPLACEMENT WINDOW JAMB DETAIL
SCALE: 3" = 1'-0"

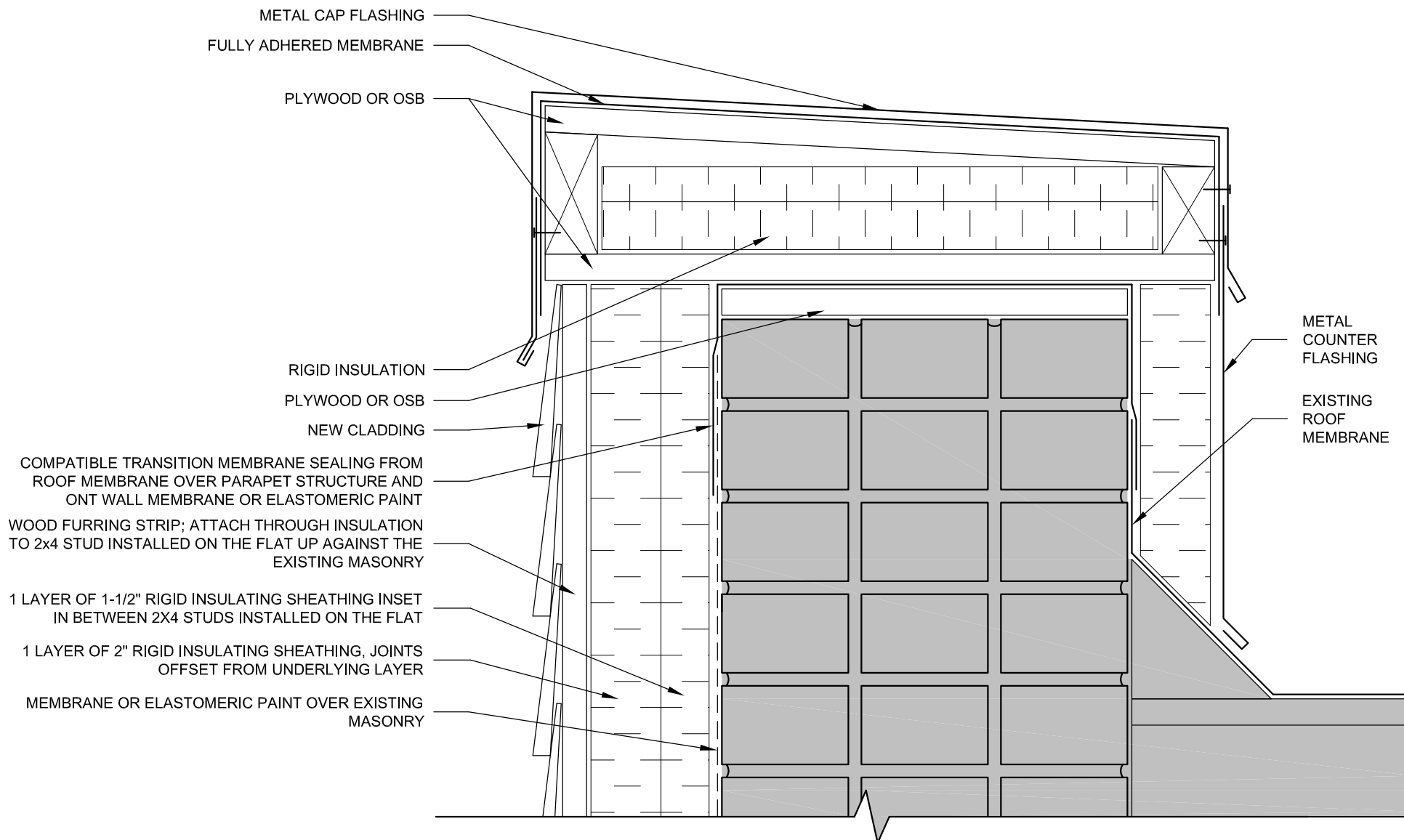


2 EXISTING REPLACEMENT WINDOW HEAD DETAIL
SCALE: 3" = 1'-0"

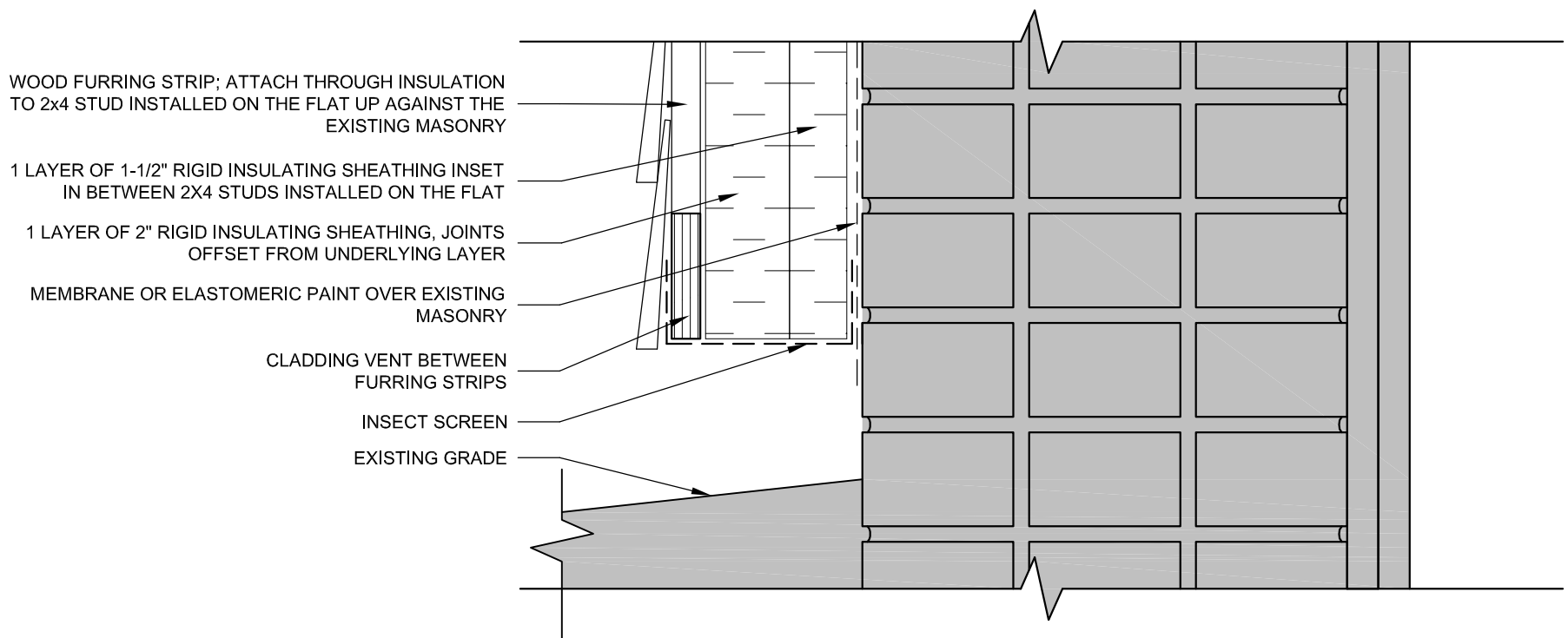


1 EXISTING REPLACEMENT WINDOW SILL DETAIL
SCALE: 3" = 1'-0"

GRAY TONE INDICATES EXISTING STRUCTURE



2 PARAPET CONNECTION DETAIL
SCALE: 3" = 1'-0"



1 FOUNDATION CONNECTION DETAIL
SCALE: 3" = 1'-0"

GRAY TONE INDICATES EXISTING STRUCTURE



Exterior Insulation over Mass Masonry Wall

Date: 2011-09-14
Drawing Title: Roof and Foundation Details

Sheet Title:

PAR

Appendix B: Insulation and Over-Cladding Work Order for Larger Multifamily Building



Multi-Family Project Work Order

* SERC Grant Project *

Address: [REDACTED]	Date: 9/30/2011
Job Number: 12-32-0042	Project Manager: [REDACTED]
Client Name: [REDACTED]	PM Phone #: [REDACTED]
Description: 3 story flat roof masonry building.	

A. PRICING

Pricing shall not be deemed to limit or modify the scope of the Work. It shall be used as a basis to evaluate the various types of work in the proposed Project Work. All areas, quantities and dimensions to be verified in the field by the contractor.

B. SUBMITTALS

Contractor MUST supply product submittals at time of bid for the following items:

- Cladding and trim materials
- Insulation materials
- Fasteners for studs, insulation, and furring
- Exterior paint

C. SPECIAL CONDITIONS

All work to comply with Illinois Home Weatherization Assistance Program Standards and Guidelines
Lead safe weatherization practices must be utilized during applicable work in accordance with IHWAP section 515.

ARCHITECTURAL

INSTALL NEW EXTERIOR INSULATION AND CLADDING SYSTEM

- Refer to the following drawings from Building Science Corporation (BSC) for bidding:
 - PAR - Roof and Foundation Details
 - REP - Existing Replacement Window Details

Refer to drawings for bidding purposes only. Contractor shall be responsible for final construction documents.
- Install new exterior insulation, fiber cement cladding, and finishing trim and accessories in accordance with supplied details, manufacturer instructions, and commonly accepted industry practices. Approximate gross wall area to be retrofitted is 5,590SF. Contractor is responsible for verifying all measurements.
- Fiber cement cladding shall be smooth surface, factory primed 4'x8' panels manufactured by James Hardie, CertainTeed, or similar. Panels may be secured with hidden brackets or on the face of the panels in compliance with manufacturer's recommendations and instructions. **Cladding shall be panels and not lap siding as indicated on drawings.**
- Fiber cement panels shall be primed on all six sides. Any field cuts shall be primed before installation to ensure that all 6 sides of the panel are sealed.
- Finish factory primed panels and trim with a minimum of one coat of high quality 100 percent acrylic exterior grade paint. Follow paint manufacturer's written product recommendations and written application instructions. Color to be selected by owner at time of pre-construction meeting.
- Contractor to remove existing parapet wall cap and install new cap assembly.
- At vertical transitions where the cladding stops and returns to the existing masonry wall (including door and window openings), color matched aluminum coil stock shall be installed as a cap. In locations where the coil stock must be face nailed, all nail heads shall be covered with an application of color matched exterior grade sealant. 1x4 composite or fiber cement trim, primed with two coats finish shall be installed on the face of the insulation layer at the edge of the aluminum capping as a stop for the fiber cement cladding.

- At all window, door, and other miscellaneous punched openings in the existing masonry wall, 1x4 composite or fiber cement trim, primed with two coats finish shall be installed on the face of the insulation layer as a stop for the fiber cement cladding. Aluminum head flashing shall be installed at every opening and integrated with the drainage system.
- Contractor to remove and reinstall the (2) existing wall mounted gutter/downspout systems.
- Contractor shall not be responsible for removing and reinstalling ventilation system ducting at the southwest corner of the building. Contractor to return exterior insulation and siding system to wall 6" away from ducting in accordance with detail noted above.

Total Material Cost:	Total Labor Cost:	ARCH TOTAL:
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BA-1311: Evaluation of Two CEDA Weatherization Pilot Implementations of an Exterior Insulation and Over-Clad Retrofit Strategy for Residential Masonry Buildings in Chicago

About this Report

This report was prepared with the cooperation of the U.S. Department of Energy's Building America Program.

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