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Cost Analysis of Roof-Only Air Sealing and Insulation Strategies on 1 ½-Story Homes in Cold Climates

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Northern*STAR*

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The work presented in this report does not represent performance of any product relative to regulated minimum efficiency requirements.

The laboratory and/or field sites used for this work are not certified rating test facilities. The conditions and methods under which products were characterized for this work differ from standard rating conditions, as described.

Because the methods and conditions differ, the reported results are not comparable to rated product performance and should only be used to estimate performance under the measured conditions.

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Unless otherwise noted, all figures were created by the NorthernSTAR Building America Partnership.

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Definitions

ACH	Air Changes per Hour
BA	Building America
BEopt™	Building Energy Optimization Software
ccSPF	Closed Cell Spray Polyurethane Foam
DER	Deep Energy Retrofit
ETMMS	External Thermal and Moisture Management System
FAM	Fluid-Applied Membrane
ft^2	Square Foot, Square Feet
Mils	Unit of Length Equal to One Thousandth of an Inch
MMBtu	Million British thermal units
OSB	Oriented Strand Board

Acknowledgments

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Executive Summary

Many approaches to ice dam mitigation in 1 ½-story homes in cold climates have been tried with varying degrees of success and failure, including interior-applied improvements to insulation and air sealing, roof raking, and exterior-applied heat tapes. In 2012, the Northern*STAR* Building America Partnership Team began exploring alternative methods to find long-term solutions to energy loss in 1 ½-story homes to save energy, improve comfort, prevent frost buildup on the underside of the roof deck, and reduce the risk of ice dam formation/reformation. *Project Overcoat: An Exploration of Exterior Insulation Strategies for 1-1/2 Story Roof Applications in Cold Climates* (Ojczyk et al. 2013a) determined that the External Thermal Moisture Management System (ETMMS) approach warranted further evaluation as a roof-only approach for maximizing opportunities for insulation, air sealing, and roof deck ventilation. The second Northern*STAR* report, *Airtightness Results of Roof-Only Air Sealing Strategies on 1 ½-Story Homes in Cold Climates* (Ojczyk et al. 2013b) investigated the airtightness impact of the roof-only, ETMMS technique on 1 ½-story homes.

This third study sought to understand the costs for using the roof-only ETMMS protocol on 1 ½-story homes in cold and very cold climates. The goal is to help residential building professionals, designers, product manufacturers, and insurance providers understand the costs and benefits of a roof-only ETMMS process when comparing methods to solve energy loss and ice dam problems.

Steve Schirber of Cocoon and Paul Eldrenkamp of Byggmeister, Inc. are two Building America industry partners from the previous Northern*STAR* studies with significant experience mitigating ice dams. They generously provided detailed cost information (materials and labor) for overcoat projects located near Minneapolis, Minnesota, and Boston, Massachusetts. Each provided costs for the core ETMMS measures applied to the roof surface area: air/water/vapor control membrane, insulation, and new roof deck. These core measure costs ranged from \$10.25–\$11.30/ft^2. They noted that full measure costs will always be higher than the core measure costs because ETMMS typically includes additional energy strategies such as air sealing and insulation at the gable wall ends and roof/wall/floor connections. Additional costs are often incurred because of complex roof planes, dormers, and the need to remove and rebuild soffits. Cocoon provided full measure cost information from two successful ice dam mitigation projects on 1 ½-story homes. These projects ranged from \$20–\$30/ft^2 of roof surface area and were inclusive of gutters, trim details, project-specific needs, and new roofing material.

The team also reviewed ancillary cost data for roof-only, interior-applied air sealing and insulation on 1 ½-story homes to improve energy efficiency provided by market rate utility and weatherization programs to help inform the discussion on what is generally done in the market. The full measures costs to improve energy efficiency ranged from \$2,260–\$2,834 compared to data from the first Northern*STAR* report where interior-applied ice dam mitigation full measure costs ranged from \$16–\$21.64/ft^2 of roof surface area.

A literature review and interviews with product manufacturers highlight a promising method to reduce costs. Fluid-applied membranes used on foundations and vertical walls for waterproofing/ air barrier could replace the self-adhering, sheet good membrane typically used by contractors today. The best way to reduce costs, however, is to increase the volume of overcoat projects a

contractor installs. As volume increases so too does speed and problem solving input that lead to cost efficiencies.

1 Introduction

One of the problems many older homes in cold and very cold climates face during winter months is the development of ice dams and moisture damage from frost on the underside of the roof deck. They are particularly a problem in 1 ½-story homes because heat is lost through the building envelope. This is important because many older homes, especially those with 1 ½-story construction, experience ice dams and resulting structural and/or interior damage and increased heating energy use. Many approaches to ice dam mitigation have been in tried in the past, including: (1) interior-applied improvements to insulation and air sealing; (2) roof raking; and (3) heat tapes.

External insulation upgrades are one potential solution to these problems. External insulation can provide a long-term solution to ice dams by providing three key components: (1) reduced air leakage via a continuous air barrier; (2) reduced heat loss via continuous insulation; and (3) effective roof ventilation. All are difficult to achieve from the inside when attic space has been converted to finished living space, rafter depth for insulation is shallow, and the roofs are complicated with dormers. Additionally, ventilating the roof deck is extremely difficult, if not impossible, from the inside.

The goal of the roof-only ETMMS process is to thoroughly insulate, air seal, and ventilate all the planes above the ½-story to control energy loss and to improve building durability and occupant comfort. Figure 1 represents the basic details of the roof plane to maximize air sealing, minimize heat loss, and provide roof ventilation without disruption to the interior.

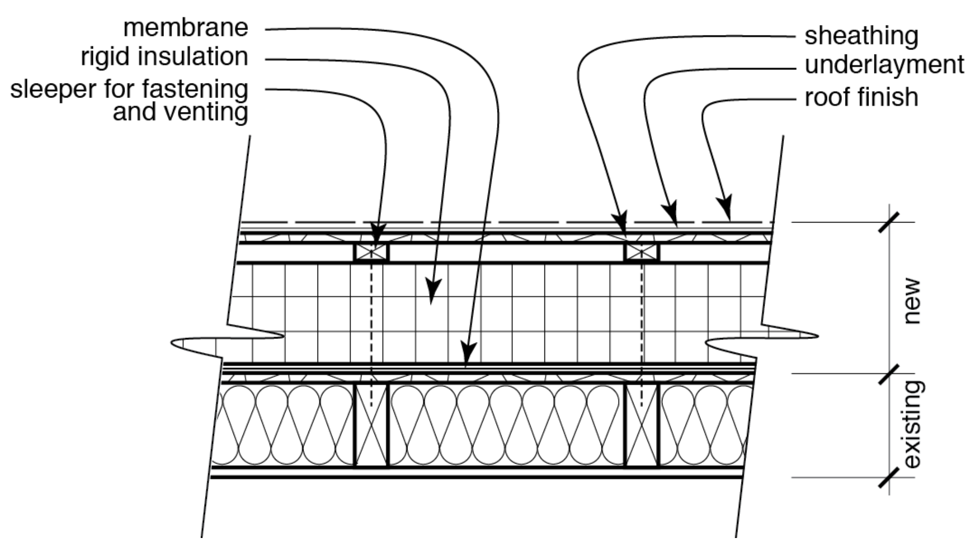

Figure 1. Details for ETMMS roof overcoat approach

Figure 2 demonstrates the fully adhered air/water/vapor control membrane layer between the existing roof decking and the layers of continuous rigid insulation that form the thermal boundary. Ventilation is designed into the system using sleepers attached through the insulation. Roof sheathing and underlayment are similar to standard roofing practices.

Figure 2. Details of ETMMS overcoat retrofit on 1 ½-story home

(Courtesy of Cocoon)

A similar process to that of the roof planes (shown in Figures 1 and 2) is applied to the gable ends. Modifications for the gable ends include the air/water/vapor control membrane carried over the roof plane edge and tied into each gable end. Insulation is applied over the membrane. Sleepers—usually 1 in. × 3 in. rather than the 2 in. × 4 in. used on the roof—provide ventilation of the wall cladding.

Figure 3 demonstrates the creation of a roof rake and open rafter tails by integrating structural framing members into the external insulation. (The image shows the air/water/vapor control membrane on the roof plane being installed first; however, it would be more efficient to apply the air/water/vapor control membrane on the gable end first so the membrane of the roof plane can wrap over it.)

Figure 3. Beginning stages of the rake details of ETMMS overcoat on a barn retrofit

(Courtesy of Tom Schirber)

The finished roof elements and gable end details are shown in Figure 4 below.

Figure 4. Finish details of ETMMS overcoat on a barn retrofit

(Courtesy of Tom Schirber)

Interior-applied air sealing and insulating is an option for the gable walls when the exterior surfaces cannot be altered, as in the case of brick cladding. For this method to be most effective, full access from ridge to attic floor is desirable. Figure 5 illustrates the use of closed cell spray polyurethane foam (ccSPF) for air sealing and insulation.

Figure 5. Details of interior-applied insulation and air sealing caused by brick cladding on the exterior

(Courtesy of Cocoon)

Several obstacles have prevented the ETMMS process from being embraced by the building industry, despite the widespread understanding that it can solve ice dam problems. The materials in the ETMMS system can be expensive. Installation can be difficult and labor intensive with roof complications such as dormers and additional roof planes and gable ends. Ensuring air barrier continuity at intersections with eaves, gables, and other architectural features requires detailed construction drawings and skilled labor.

This study sought to better understand basic costs to install ETMMS on 1 ½-story homes in cold and very cold climates, the additional costs for addressing roof complications, and any alternate products or processes to reduce costs. It also sought a general understanding of how the cost of ETMMS compares to other roof-only insulation and air sealing solutions.

2 Project Context

2.1 Background

Figure 6 from the University of Minnesota Extension Service (UM 2010) demonstrates how heat loss through the building envelope of a 1 ½-story home can promote ice dam formation and reduce building durability and energy efficiency.

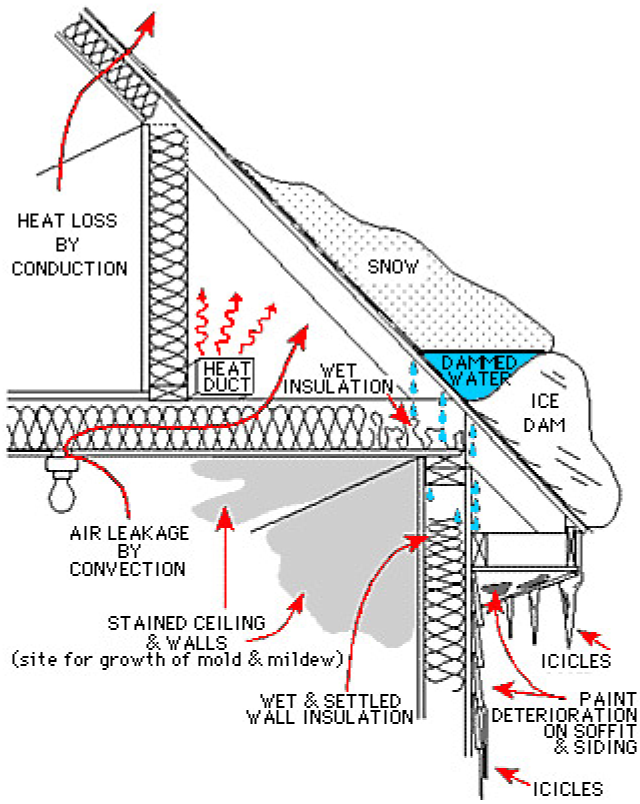

Figure 6. How an ice dam forms

(Courtesy University of Minnesota Extension)

Ojczyk et al. (2013a) estimated that there are several million 1 ½-story homes in cold climate states nationwide. Homeowners' desire to expand living area into unused attic space, however, has resulted in less than optimal conditions for providing energy efficiency, comfort, and long-term durability. This house type suffers from frequent ice dams caused by one or more shortcomings that are inherent in the home design or that result from attempted improvements, including:

- Difficulty upgrading insulation, air sealing, and ventilation in a ½-story with finished walls and floors
- Difficulty providing adequate insulation in vaulted ceilings with shallow rafter depths
- Lack of raised heel energy truss and difficulty preventing thermal bridging of interior heat to the roof deck even with high R-value foam insulation in a vaulted ceiling

- Difficulty in venting the roof deck of vaulted ceilings in high snow load regions
- Challenges to properly vent the roof deck with multiple valleys created by dormers and architectural details
- Roof obstructions and penetrations such as chimneys, vent and soil stacks, and skylights
- Failure to maintain air barrier continuity as the air control layer shifts from wall to ceiling, to knee wall, to sloped ceiling to flat ceiling.

The difficulty in air sealing leaves this house type vulnerable to the possibility that one half or more of the total air leakage is at or above the first floor top plate. Even the top attic space has limited clearances for very high levels of insulation. Although the lower portion (knee walls with crawlspace) may have better insulation values, it is usually compromised by air movement. Proper alignment of the insulation and air barrier is often the most difficult challenge.

These issues frequently cause excess heat loss to reach the roof, which contributes to ice dam formation and compromises structural durability and integrity. Ice dams and melted snow can cause significant premature roofing failure, wet insulation, soffit/fascia deterioration, paint failure on claddings or interior surfaces, interstitial and interior mold growth, structural decay, further exacerbation of rot and water damage, and safety risks from falling ice, structural collapse of roof overhangs, and shearing of deck assemblies from ice and snow fall.

According to the Insurance Information Institute (III 2012), losses caused by water damage and freezing have increased significantly across the country from 14.6% of all claims in 2005 to 23.7% in 2009 and were the second most claimed loss behind wind and hail. The Iowa Insurance Institute Communications (IIIC 2011) reported that winter storms accounted for 7.4% of catastrophe losses nationwide from 1991 to 2010, or an average of $1.3 billion/year. In 2010, more than $1 billion in claims from winter storms were experienced on the East Coast alone (AW 2011). The Insurance Information Institute is predicting that the severe weather of 2014 will cause it to be ranked as one of the top five costliest winters since 1980 (III 2014).

It is difficult to isolate the number of homeowner claims resulting from ice dams, because ice dam claim information is part of total winter storm claims. What is even less understood (because data are lacking) is the level of ice dam recurrence after an attempted improvement. Yet, a review of insurance company websites seems to indicate that ice dam prevention is an important issue to address. Many insurance companies, including State Farm (SF 2012) and the Insurance Institute for Business and Home Safety (IBHS 2012), offer ice dam information on their customer websites.

Ojczyk et al. (2013a) explored external roofing solutions for existing 1 ½-story homes. The exploration focused on identifying an external approach with the potential to provide cost-effective, long-term, scalable solutions that could be tested in the field. An extensive literature review was conducted to examine four external insulation and air sealing techniques used in new construction, deep energy whole-house retrofits, and roof-only applications to determine which solution appears most effective in preventing heat loss through the roof and ice dam formation on 1 ½-story homes. The four techniques reviewed included ETMMS, structural insulated panels, over-roofing, and spray foam. The overall intent was to determine which external overcoat approach warranted further evaluation as a roof-only approach for maximizing opportunities for insulation, air sealing, and roof deck ventilation to yield reduced air exfiltration and energy loss and reduce ice dams.

The literature review revealed a large body of data and design/installation details for overcoat approaches for whole-house (foundation wall plus above-grade wall plus roof) applications, whereas other exterior overcoat systems were not well supported through research. Cost data for roof-only external overcoat applications for existing homes could not be found.

Ojczyk et al. (2013a) also included interviews with six contractors in cold climate states that had experience using external overcoat solutions as part of whole-house or roof-only energy improvements and/or ice dam mitigations. All the builders commented that they would prefer to use the external overcoat method to mitigate ice dams and improve energy performance. However, perceived cost increases, competition from lower priced interior solutions, and lack of supportive data showing the air sealing and heat loss prevention opportunities from exterior overcoat approach limited their success.

That study also indicated a wide range of costs for ice dam mitigation strategies, and the approach applied by each contractor varied—driven by the complexity of the roof and the need to maintain architectural or historic features. The contractor interviews indicated that ice dam mitigation in 1 ½-story homes via an interior approach is not always less expensive than external approaches. One contractor reported an ice dam solution applied from the interior resulted in a full measure cost of $\$16/ft^2$ of roof surface area. In this project, the roof decking was removed and rafter cavities sealed and insulated with medium-density spray foam. Another contractor used an interior approach whereby the roof deck was removed and rafter cavities filled with 7 in. of foil faced polyisocyanurate sealed with spray foam. This resulted in a full measure cost of $\$21.74/ft^2$ of roof surface area.

Neuhauser (2012) investigated opportunities for air sealing and insulation of attics and roofs in masonry bungalows eligible to participate in a Chicago-area weatherization program. The homes had 925–1,700 ft^2 of conditioned living area on the first floor with an average 1,216 ft^2. Homeowners who did not intend to use the attic for living space insulated and air sealed at the attic floor with an average full measure cost per project of $3,493. Bungalows that had finished ½ stories for living space were insulated and air sealed with a roof rafter strategy that also included removal of floorboards at the perimeter for additional air sealing and insulation. The average full measure cost per project was $11,087. The research also found air leakage reduction and predicted energy performance of these strategies to be similar. The average air leakage reduction was approximately 55% for both the attic floor and roof rafter strategies.

A similar outcome in air leakage reduction was achieved using two approaches based on existing conditions. This alignment of results could be attributed to the fact that contractors who work in the weatherization program are required to follow specific protocols for installation and quality assurance. Also, a finished ½ story resulted in an average cost increase of 3 times to achieve a similar air sealing result.

A Northern*STAR* Industry Partner, Nor-Son, recently reported on an ice dam mitigation retrofit for a single-level home in north-central Minnesota. The company used a vacuum, spray, blow approach whereby the old insulation on the attic floor was removed, and the floor vacuumed clean to remove fine particles. ccSPF was applied to the attic floor for air sealing, vapor barrier, and to provide some insulation. Fiberglass insulation was blown over the spray foam to create a total R-49. Ventilation was added to each rafter cavity. The full measure cost to the homeowner was $10/ft^2. This retrofit was completed in the fall of 2013 and no ice dams were reported during the winter of 2014.

Ojczyk et al. (2013b) provided supporting data on air exfiltration for roof overcoat projects using the ETMMS approach. Data from contractors using ETMMS to mitigate ice dams as well as supplemental data from Building America (BA) industry partners using an interior-only approach to improve energy efficiency shows a large variation in airtightness improvement in both the exterior- and interior-applied air sealing processes. Both approaches, however, can significantly improve airtightness—some achieving close to 50%.

As for the two projects that did follow the ETMMS protocol, the airtightness results were varied. One reduced air exfiltration by 47%, the other by 21%. One project points to the opportunities to achieve high reductions in air leakage from a roof-only approach; the other highlights the consequences of starting with greater obstacles. In this home, the interior walls of the attic living space were in place and could not be opened from the inside. This left a large percentage of the brick-clad gable end walls without air sealing. Air leakage reduction was less than anticipated. Thermal imaging results from each project, however, illustrate significant improvements in airtightness achieved at the roof planes—a goal when mitigating ice dams. Also, the home that achieved fewer airtightness improvements had undergone energy improvements during a previous remodel.

Although predicted effectiveness of a solution is an important component to consider in determining best approach for a solution, understanding cost is also imperative. This study sought a better understanding of the costs to use the roof-only ETMMS as a solution for ice dams on 1 ½-story homes.

2.2 Relevance to Building America Goals

The goal of the U.S. Department of Energy's BA program is to reduce home energy use for existing homes by at least 50% compared to pre-retrofit energy use. Improvements to energy efficiency, however, are not the only desired outcomes. Because energy loss can also involve moisture transport, energy efficiency improvements can improve building durability.

This study focused on the cost of external energy solutions to reduce ice dam problems in 1 ½-story home types such as Cape Cods and Bungalows, of which there are several million (Ojczyk et al. 2013a)—many located in urban and first-ring suburbs of small to large communities in cold and very cold climates. The team sought to identify opportunities to maximize the effectiveness of the ETMMS approach while offering options to reduce the cost and complexity of the process. Results will help support building professionals, design professionals, product manufacturers, and insurance companies who want to provide ice dam solutions to clients but need supportive data.

The ETMMS strategy has a construction delivery advantage as well. The work can be performed from the exterior with little inconvenience to the interior offering an alternative solution to the disruption of remodeling.

3 Research Project Description

Building science principles and field experience suggest that adding insulation outside existing building envelope assemblies confers a variety of energy efficiency and durability benefits compared to interior insulation upgrade solutions. ETMMS was conceived for new construction as a whole-house overcoat providing continuous environmental control layers on the exterior from footing to roof peak.

The perceived high cost of external energy upgrades remains an obstacle to widespread adoption in the industry. This third body of work by the Northern*STAR* team is designed to address costs and potential cost reductions for external energy retrofits on roofs of 1 ½-story homes in cold climates.

3.1 Research Questions

The following research questions served as a guide:

- What are the installation costs and what value engineering can be applied?
- What components and techniques are available that can be substituted in the overcoat application process to minimize the cost associated with overcoat for roofs?
- What construction methods will ensure effectiveness while enhancing efficiency?
- What lessons were learned from previous attempts at exterior overcoat application by some contractors?

3.2 Study Approach

3.2.1 Cost Review of Exterior-Applied Air Sealing and Insulation Strategies

Two BA industry partners who participated in the previous Northern*STAR* overcoat projects and who have significant experience using ETMMS and ETMMS-like processes were interviewed about installed cost data. The two contractors were:

- Steve Schirber, general manager, Cocoon, Eden Prairie, Minnesota
- Paul Eldrenkamp, owner, Byggmeister, Inc., Newton, Massachusetts.

Information sought included:

- Costs for the basic ETMMS process
- Estimated costs for roof complications such as dormers, intersecting planes, additional gables, and other concerns
- Suggested methods or materials to reduce costs associated with ETMMS.

3.2.2 Cost Review of Model Home Using Exterior-Applied Insulation and Air Sealing Strategies

A model 1 ½-story house was used to demonstrate the cost computation for a roof-only ETMMS installation using installed pricing as provided by Cocoon for a cold climate retrofit in the Minneapolis, Minnesota, area. It provides a look at a simple retrofit process whereby all roof planes are obstacle free and the gable ends are fully accessible for insulation and air sealing from the exterior.

3.2.3 Alternate Materials and Processes Review

A literature review and interviews with product manufacturers were conducted to gain further insight into cost reductions using alternate materials and processes.

3.2.4 Cost Review of Interior-Applied Air Sealing and Insulation Strategies From Industry Partners

Ojczyk et al. (2013b) discussed how several BA industry partners offered airtightness data from interior-applied, roof-only energy improvements to 1 ½-story homes participating in market-rate utility and weatherization programs. All three companies that provided air leakage data are BA industry partners and assist the Northern*STAR* BA partnership in research:

- Center for Energy and Environment, Minneapolis, Minnesota
- Neighborhood Energy Connection, St. Paul, Minnesota
- Sustainable Resource Center, Minneapolis, Minnesota.

Cost data associated with the interior-applied improvements were sought for further insight into the range of costs generally experienced in the field for roof-only energy improvements on 1 ½-story homes.

3.2.5 BEopt Energy Cost Modeling

The Northern*STAR* team used the Building Energy Optimization (BEopt™) version 2.2.0.0 to better understand the potential reduction in annual energy usage and utility costs that could result from the addition of exterior-side air sealing and insulation to the roof and gable walls.

The software was used to simulate the energy performance of a reference home and homes modified through the application of insulation and air sealing. Two strategies were modeled: upgrades applied to the existing thermal boundaries (attic floor, knee wall, and finished ceiling), and an overcoat approach, involving application of continuous rigid insulation on the existing roof sheathing. The Northern*STAR* team developed the reference home, named NSTAR 1, for various research projects to be conducted on 1 ½-story houses. The 28-ft × 36-ft foundation with full basement, first floor, and attic living space yielded 2,664 ft^2 of conditioned living space. The default parameters included in the BEopt program were upgraded to reflect housing typical to the Minneapolis area for the base case. These upgrades are shown below in Table 1.

The modeled energy performance of the NSTAR 1 reference home was compared to the modeled energy performance of a home upgraded using traditional interior-applied air sealing and insulation applied to the attic floor, knee wall, and finished roof (Figure 7), and the reference home upgraded using the roof-only ETMMS external application (Figure 8). All modeling was computed using Minneapolis, Minnesota, as the cold climate location. The colored planes represented in the figures reflect the presence (Figure 7) or absence (Figure 8) of knee walls as separators between thermal zones.

Table 1. Upgrades to BEopt Default Parameters To Reflect Housing Typical to Minneapolis, Minnesota

	BEopt Default	Minneapolis Upgrade
Wall and Knee Wall Insulation	R-3.6 (uninsulated)	R-8.9 (R-7 fiberglass batt)
Finished Roof Insulation	R-0	R-9 (R-7 fiberglass batt)
Attic Floor Insulation in Knee Wall Space	R-12.6 (fiberglass batt)	R-26.6 (R-25 fiberglass batt)
Air Leakage (ACH50)	15	7
Windows	Single pane, metal frames	Double pane clear, nonmetal frames

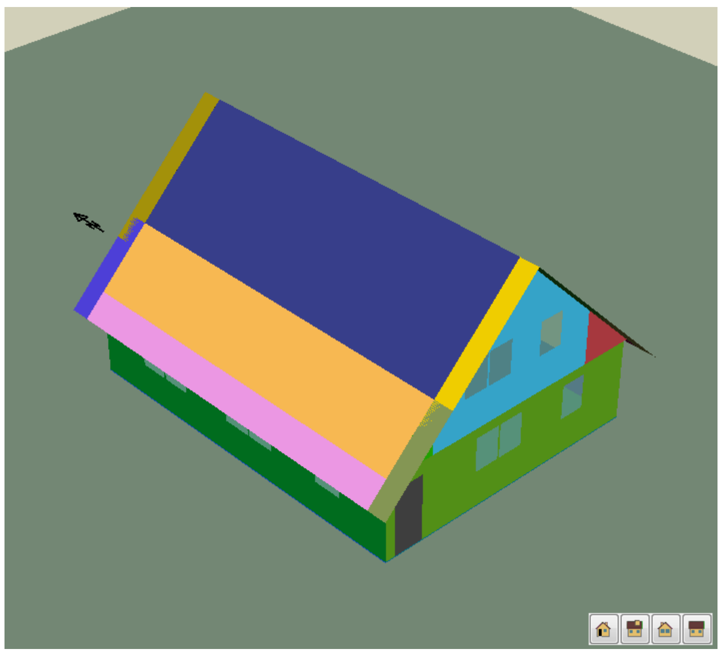

Figure 7. Interior-applied insulation and air sealing

The column on the left in Figure 9 labeled “existing” represents the source energy use per year (MMBtu/yr) of the NSTAR 1 reference house. The center column labeled “knee wall” represents the source energy reduction of 7% resulting from interior-applied upgrades to the attic floor (to R-38), knee walls (to R-13), and finished roof (to R-13) along with air sealing to achieve 4 ACH50. Heating energy was reduced by 13%. The column on the right labeled “overcoat” represents the impact on source energy use after the installation of continuous exterior polyisocyanurate insulation at R-39 and air sealing to achieve 4 ACH50. The computer simulation indicates a 14% reduction in whole-house energy use compared to the NSTAR 1 reference with a reduction in heating energy of 26%.

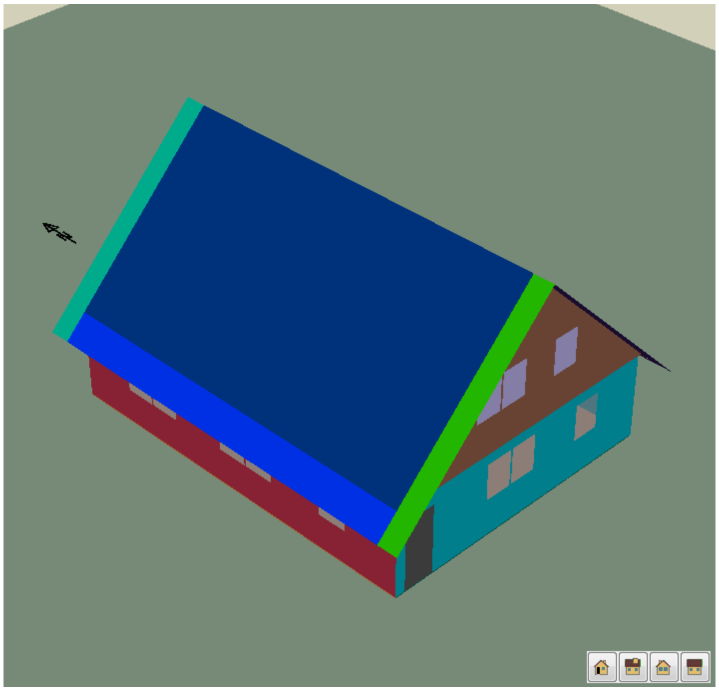

Figure 8. Exterior-applied insulation and air sealing

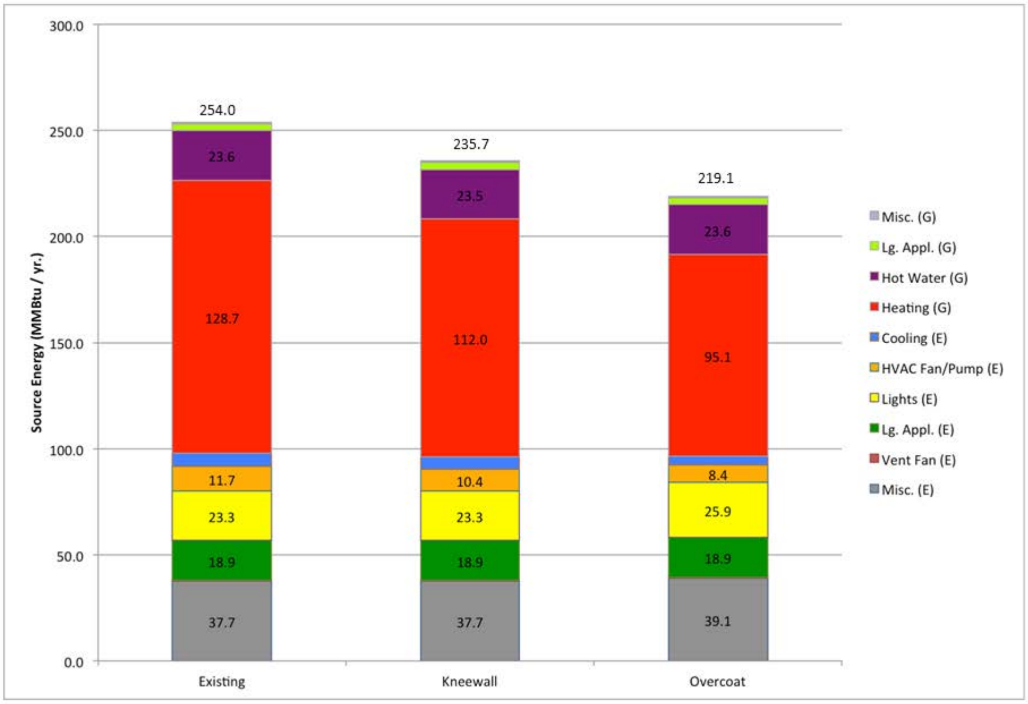

Figure 9. Source energy use per year

Figure 10 represents predicted utility cost reductions. For this computation, the cost of natural gas is assumed to be $0.77/therm, representing the local utility rate. Gas prices in the Midwest are significantly lower than the BEopt default of $1/therm. Even though the default gas price was adjusted for all three houses to the current local rate, it illustrates potential differences in utility savings as gas prices change per region.

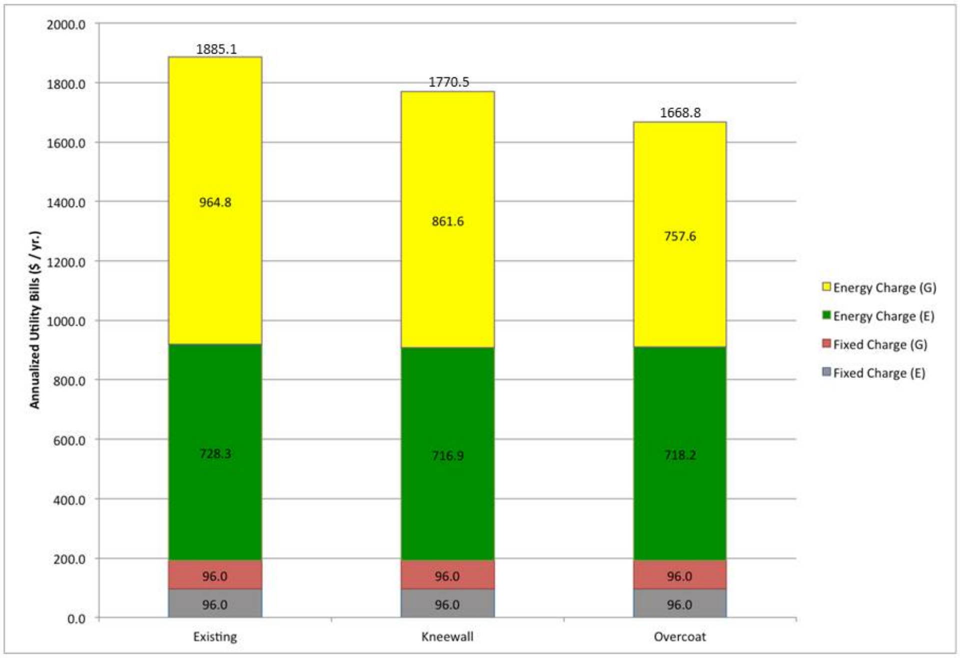

Figure 10. Utility cost reductions from roof-only upgrades

When energy savings are converted to utility costs per year, the interior upgrades are predicted to reduce utility bills by 6% and the overcoat retrofit by 12%. Heating costs were reduced 11% and 21%, respectively.

The BEopt simulation, however, presented some notable challenges to energy usage reductions and utility cost predictions for 1 ½-story homes. The software does not enable modeling of the small attic space above the ½-story. Gable ends are treated as an exterior wall in line with the first floor. Additional insulation of these areas, per the ETMMS method, could not be modeled. The BEopt software does not fully model a foundation wall with above-grade and below-grade components. The full impact of ETMMS on predicted energy and costs savings, therefore, may not be reflected in source energy use or the annualized energy bills. A homeowner's actual energy cost savings from ETMMS may be underrepresented using the BEopt software.

4 Results

4.1 Cost Review of Exterior-Applied Insulation and Air Sealing Strategies

4.1.1 Interview With Steve Schirber, Cocoon

In Ojczyk et al. (2013b), Cocoon provided testing results from two ETMMS roof-only projects located in Minnesota where the owners were seeking ice dam solutions. These projects represent successful realization of improved energy performance from measures motivated by ice dam mitigation.

The St. Louis Park home in Figure 11 below had one dormer and three gables. It was clad in brick on all exterior walls. The interior of the ½ story was recently gutted and fully accessible. The aluminum soffit, fascia, gutters, and downspouts were replaced with the same.

Figure 11. Front view of Cocoon St. Louis Park house post-retrofit

(Courtesy of Cocoon)

The Edina home, shown in Figure 12 below, had no dormers but five gables. It was clad in brick on all exterior walls. The interior of the ½ story was completely finished, and the only accessible part of the gable ends was in the small space above the ceiling. The wood rake, eave, and decorative details were replaced with the same. Copper gutters and downspouts were added.

Figure 12. Front view of Cocoon Edina house post-retrofit

(Courtesy of Cocoon)

Both houses underwent complete roof overcoats that were achieved through the same basic process. The products and design details varied because of the different roof typologies and obstacles. The Cocoon process for achieving the ETMMS roof-only retrofits is listed sequentially here:

1. Removed all the roofing materials down to the existing roof deck. Gutters, fascia, and soffit were also removed and rafter tails were cut back to the existing top plates using a chainsaw approach. The roof deck was removed at roof/gable wall connection.
2. Revented the existing bath fans out the gable walls to reduce the number of roof penetrations.
3. Air sealed the roof/wall connection at the top plates using ccSPF.
4. Air sealed roof/gable wall connections from the exterior using ccSPF.
5. Air sealed the roof/gable wall connections from the interior. Optimal air sealing in the ETMMS process would occur from the exterior by wrapping the roof plane membrane over a membrane applied to the wall sheathing on the gable ends. Because these two homes were clad in brick, the air sealing had to occur from inside the attics. The attic in the St. Louis Park house was fully accessible, allowing for greater air sealing continuity.
6. The ½-story in the Edina house was recently finished, and the only accessible gable ends were above the ceiling.
7. Applied air/water/vapor control membrane primer to the roof deck.

8. Applied the air/water/vapor control membrane over the exposed roof deck and lapped over the exterior walls.
9. Installed the new soffit framing and subfascia to accommodate for the additional thickness of the roof and to match the existing architectural style of the house.
10. Installed two layers of rigid insulation board, seams staggered, over the air/water/vapor control membrane.
11. Installed furring strips over the rigid insulation board to allow for continuous ventilation using long screws appropriately sized and rated for engineering specifications.
12. Attached the new roof decking to the furring strips.
13. Extended the roof waterproofing and finish materials over the decking: extended plumbing stacks and followed proper flashing protocol.
14. Installed the new continuous soffit and fascia venting and insect barrier before the gutters were installed.
15. Installed roofing materials along with a continuous ridge vent.

The two Cocoon homes also underwent a “chainsaw” removal of the existing architectural details and soffits to maximize opportunities to align air barriers, insulate at the roof/wall connections, and provide ventilation for the new roof deck. Figure 13 below represents the chainsaw removal of the soffits.

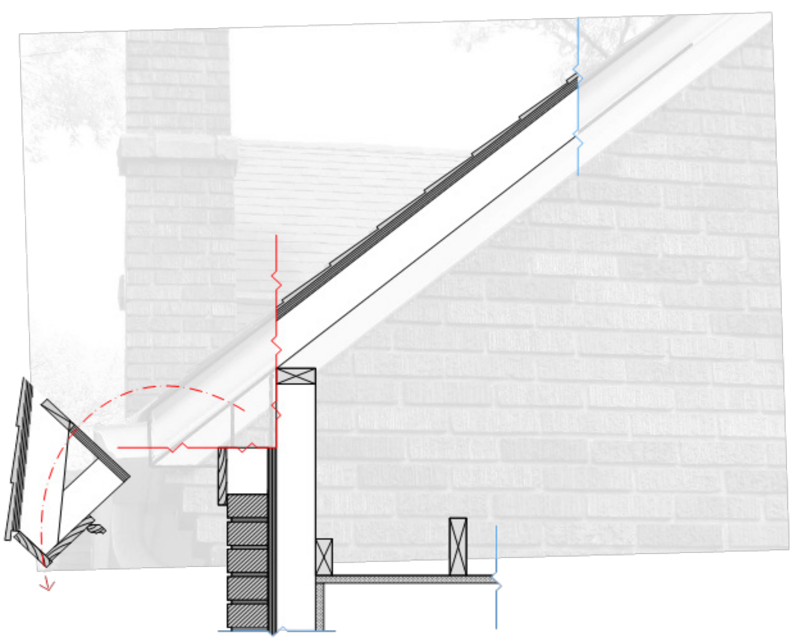

Figure 13. Removing the soffit for an ETMMS approach illustrated by superimposing a drawing of the process over a photograph of the home

(Courtesy of Cocoon)

The chainsaw removal and thickness of the ETMMS components require rebuilding of architectural components and soffits for venting. Figure 14 below shows the alignment of air barriers and insulation layers to demonstrate the impact on trim details and soffits:

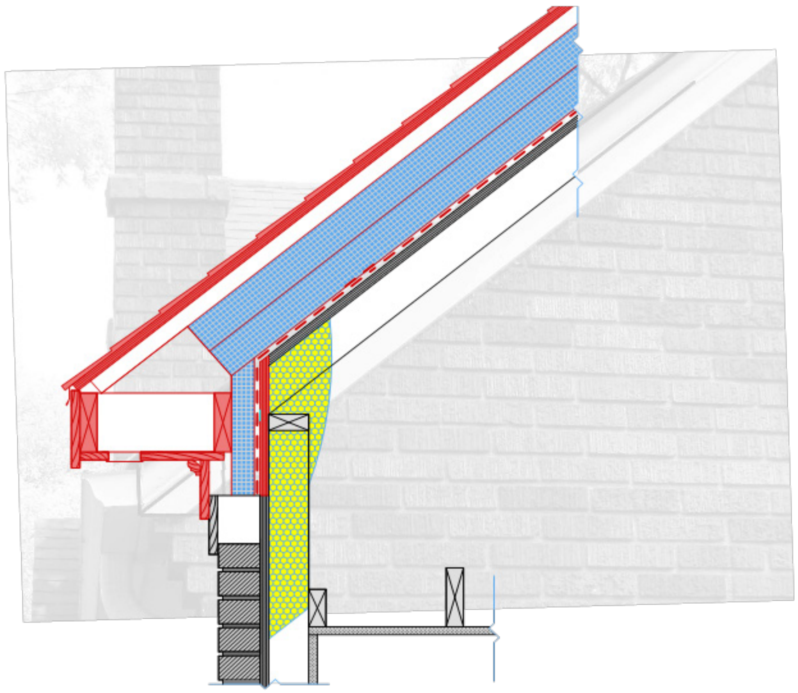

Figure 14. Insulation, air barrier alignment, and soffit reconstruction illustrated by superimposing a drawing of the process over a photograph of the home

(Courtesy of Cocoon)

The St. Louis Park home had one window that would be impacted negatively by the addition of the extra thick roof insulation. The Edina home had two such windows. Figure 15 represents the copper window pan, or “bird’s mouth” solution to accommodate the windows and insulation thickness.

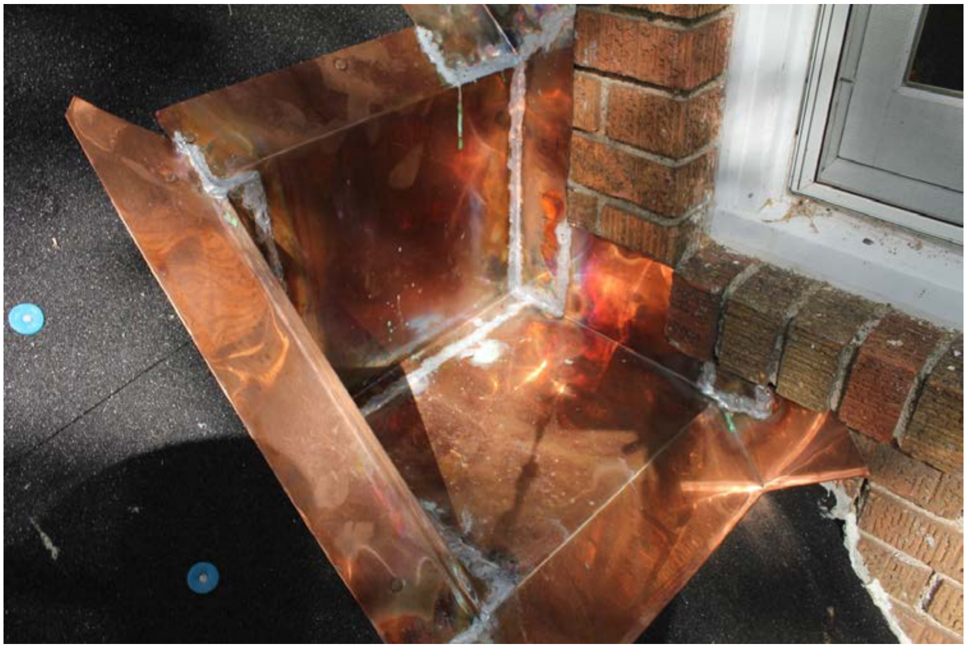

Figure 15. Creating a copper "bird's mouth" to accommodate thickness of insulation layers without impeding window

(Courtesy of Cocoon)

Each home also had an original roof deck composed of 1-in. × 10-in. skip sheathing—a common feature in older homes. Because there were gaps greater than ½ in. between the boards, each roof had to be redecked to meet before the ETMMS components were added.

Cost estimating for ETMMS has six basic parts to consider:

- Part 1 is the easiest to compute because it relates to the core ETMMS measures that are applied to the roof planes and are typically computed in cost per square foot. These components are the air/water/vapor control membrane, exterior insulation, sleepers and fasteners, and roof decking.
- Part 2 is related to removing and rebuilding parts of the structure to maximize air sealing. This includes the removal/rebuild of the soffit frame work—often referred to as a "chainsaw" approach (Figure 13). It may also include removal of part of the roof deck to access the roof/gable wall connection for air sealing.
- Part 3 is related to air sealing and insulation at the roof/wall and roof/gable wall connections. It may also include air sealing and insulation of the gable walls from the interior of the house if the gable wall cladding cannot be removed, as in the case of brick (Figure 5).
- Part 4 includes the cost for the air/water membrane, insulation, and sleepers/fasteners applied to the exteriors of the gable walls.
- Part 5 includes all other components that could be assigned as a cost to the energy retrofit such as roof deck repair, dormers, project-specific needs such as the bird's mouth insets

(Figure 15), roofing material, wall cladding, soffit/fascia/rake rebuild, and gutters/downspouts.

- Part 6 is a method to communicate full measure cost in a consistent manner such as full measure cost divided by square feet of roof surface area as used by Cocoon.

Table 2 demonstrates measure costs for materials and labor (installed cost) provided by Cocoon.

Table 2. Average Costs for ETMMS Measures on Roof-Only Overcoat Provided by Cocoon for Two Projects Completed in the Minneapolis, Minnesota area

ETMMS Measure	Product Name	Installed Measure Cost
Roof Plane Air/Water/Vapor Control Membrane	Grace Perm-A-Barrier Detail Membrane + Primer	$2.50/ft^2
Roof Plane Exterior Insulation	2, 3-inch fiberglass felt-faced polyisocyanurate + canned spray foam for seams	$4.00/ft^2
Roof Plane Sleepers + Fasteners	2 in. × 4 in. laid flat	$2.00/ft^2
Roof Deck + Fasteners	½-in. oriented strand board (OSB) + 12-in. lag screws	$1.75/ft^2
Subtotal for Core ETMMS Measures on Roof Planes		**$10.25/ft^2**
Soffit Tear-Off and Reframe		$22–$30/linear ft
Foaming of Edges To Connect Wall to Roof and Gable End	ccSPF	$1–$1.50/board ft
Insulation and Air Sealing of Gable Ends From Interior[a]	ccSPF	$1–$1.50/board ft
Gable End Exterior Membrane[b]	Grace Perm-A-Barrier Detail Membrane + Primer	$2.50/ft^2
Gable End Exterior Insulation, Sleepers + Fasteners[b]	1, 3-in. fiberglass felt-faced polyisocyanurate + canned spray foam for seams, 1 in. × 3-in. sleepers laid flat	$3/ft^2
Soffit, Fascia, Rake Rebuild	Wood	$30/linear ft
Soffit, Fascia, Rake Rebuild	Aluminum	$5–$8/linear ft

[a] ccSPF can be used on the interior of the gable wall for air sealing and insulation when the exterior of the gable wall cannot be altered, as in the case of brick cladding.
[b] When the membrane and insulation can be installed on the exteriors of the gable ends, they can be tied into the roof plane to create a continuous air/water barrier extending above the attic floor.

The average installed cost for the core ETMMS measures applied to the roof planes in the two Cocoon projects was $10.25/ft^2. The full measure costs for the St. Louis Park home was $20/ft^2 of roof surface area. It includes the core ETMMS measures (part 1), the cost components in parts 2–5, and new asphalt shingles, gutters/downspouts, and copper window pan. (The full measure cost was computed using the project total divided by the square feet of the roof surface area as per part 6.) The Edina house, with its unique details including wood trim, copper window pans, gutters/downspouts, and asphalt shingles resulted in a full measure cost of $30/ft^2 of roof surface area.

Steve Schirber of Cocoon commented that dormers are usually a small percentage of the overall surface area of the roof. The cost to add ETMMS to them would be figured on a percentage basis much the same way the reroofing of a dormer would be calculated in the overall cost of the roof. If new windows are required, the cost for windows and proper installation would need to be included as well.

In regards to materials or processes that could result in cost reductions, Schirber has not used alternate materials in his ETMMS projects. However, he has experienced cost reductions as his volume of ETMMS ice dam projects increased in a season. Repetition enables his crew to become familiar with process and expectations and apply innovation. He also commented that overall project costs are generally lower and the opportunities to apply ETMMS are greatest when a homeowner is already planning major exterior renovations such as the replacement of roofing and wall cladding. The homeowners in both the Edina and St. Louis Park homes were planning roofing replacement.

4.1.2 Interview With Paul Eldrenkamp, Byggmeister, Inc.

Byggmeister, Inc. has been involved with many whole-house deep energy retrofit projects in the Massachusetts area, where a modified ETMMS process is applied to the walls and the roof. Because Byggmeister's deep energy retrofit projects address both ice dam mitigation and whole-house energy efficiency improvements, the company typically has access to interior walls and roof rafters to install additional insulation. With the resulting R-60 in the roof, they typically do not ventilate the roof deck. Table 3 provides core measure costs provided by Paul Eldrenkamp for Byggmeister's modified-ETMMS approach.

Table 3. Average Installed Costs for Air/Water Membrane, Insulation, and Roof Deck/Fasteners for a Modified-ETMMS Overcoat Provided by Byggmeister, Inc.

ETMMS Measure	Product Name	Installed Measure Cost
Roof Plane Air/Water/Vapor Control Membrane	Grace Perm-A-Barrier Detail Membrane + Primer	$1.15/ft^2
Roof Plane Exterior Insulation	3, 2-in. polyisocyanurate	$6/ft^2
Roof Plane Sleepers + Fasteners		N/A*
Roof Deck + Fasteners		$4.15/ft^2
Subtotal for Core ETMMS Measures on Roof Planes		**$11.30/ft^2**

*Byggmeister uses an unvented attic system and therefore does not use sleepers and fasteners.

Byggmeister has encountered many roof complications and existing conditions, including intersecting roof planes, dormers, architectural details, abnormal house height, and chainsaw retrofits. Paul Eldrenkamp creates a preliminary estimate for homeowners using a 3:1 rule: A roof modified with an external overcoat approach costs, at a minimum, 3 times higher than the cost of reroofing the same roof with asphalt shingles. This simple ratio makes it easier to give clients a rough estimate to test the waters on their commitment to solve ice dam and energy loss issues.

4.1.3 Cost Review of Model Home Using Exterior-Applied Insulation and Air Sealing Strategies

To further demonstrate the costs associated with the ETMMS components for a roof-only overcoat retrofit on a 1 ½-story home, a model home, as shown in Figure 16, was created for discussion purposes. The measure costs used in the demonstration were provided by Cocoon for a cold climate retrofit in the Minneapolis, Minnesota, area. It provides a look at a simplified process whereby all roof planes are equal planes and obstacle-free. The gable ends are fully accessible for insulation and air sealing from the exterior of the house. The details of this model single-family, 1 ½-story house are:

- Footprint = 36 ft × 28 ft
- Second floor height at the ridge = 14 ft, 4 ¾ in.
- First floor height = 8 ft.

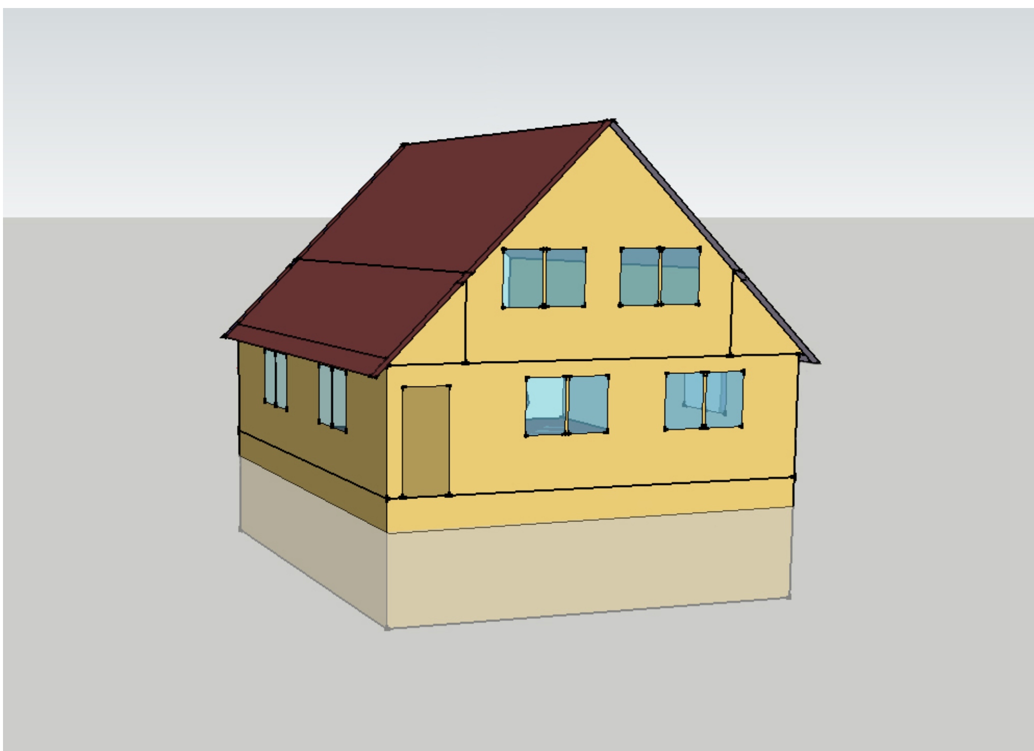

Figure 16. 36 ft × 28 ft model home with 8 ft first floor height and second floor height 14 ft, 4 ¾ in. at the ridge used to demonstrate calculations for ETMMS roof-only retrofit

The estimated installed pricing provided in Table 4 is representative of the model house and is presented for discussion only. Each ice dam mitigation project should be estimated individually to account for house features, existing conditions, client goals, contractor pricing, and current material/labor pricing.

The installed pricing used in Table 4 is based on information provided solely by Cocoon and its experience with ice dam mitigation in the upper Midwest. It does not represent industry averages or standards for practice.

Table 4. Estimated Costs for ETMMS Measures on Model Home Using Installed Measure Pricing Provided by Cocoon

ETMMS Measure	Installed Measure Costs Used by Cocoon	Cost for Model Home
Roof Plane Air/Water/Vapor Control Membrane	$2.50/ft^2$	$3,600
Roof Plane Exterior Insulation (2, 3-in. Layers Polyisocyanurate)	$4/ft^2$	$5,760
Roof Plane 2-in. × 4-in. Sleepers + Fasteners	$2/ft^2$	$2,880
Roof Deck + Fasteners	$1.75/ft^2$	$2,520
Subtotal for Core ETMMS Measures on Roof Planes	**$10.25/ft^2$**	**$14,760**
Eave Tear-Off and Reframe	$22	$1,584
Foaming of Edges To Connect Wall to Roof (Estimate Depth of 3 in. of Foam Board Feet per Linear Foot)	$1/board ft	$216
Gable End Membrane	$2.50/ft^2$	$980
Gable End Exterior Insulation (1, 3-in. Layer Polyisocyanurate), 1 in. × 3 in. Sleeper + Fasteners	$3/ft^2$	$1,176
Soffit, Fascia, Rake[a] Rebuild—Aluminum	$5/linear ft	$760
Total for Additional ETMMS Measures[b]		**$19,476**

[a] There is no corresponding note

[b] Full measure cost will likely be higher and could include measures such as roof tear off, repair of existing roof deck, roofing material, gutters/downspouts, and cladding material.

The $19,476 total yields a partial measure price of $13.53/ft^2$ of roof surface area. This number represents the cost for the ETMMS-components. It does not represent the full measure cost to complete a project. The full measure cost of a real project could include tear-off of existing roofing material, repair of existing roof deck to meet code, replacement of roofing material, addition or replacement of gutters and downspouts, and the replacement of cladding material. This simple illustration also assumes there are no additional costs due to complications from chimneys, intersecting planes, architectural/historic details, or dormers. It does, however, provide insight into how the cost of ETMMS components might contribute to the full measure cost of an overcoat project.

4.2 Alternate Materials and Processes

One potential material that could help reduce installed costs on a roof-only ETMMS retrofit would be a fluid-applied membrane (FAM), also known as liquid-applied membrane. It could take the place of the self-adhering air/water/vapor control membrane reportedly used in

ETMMS. FAMs are often sprayed or rolled on to a substrate to create a self-adhering barrier that resists the flow of air into and out of the home and act as a barrier against liquid moisture. These products are commonly used as foundation waterproofing. In recent years new formulations have been created for vertical wall surfaces to replace house wraps. Pricing varies widely.

The following represent some of the products available. None of the companies have tested their FAMs for durability, water-resistive properties, and performance on sloped roof surfaces and with the large fasteners required for thick insulation materials. All safety precautions for working on roof surfaces would still be necessary.

Marflex foundation waterproofing is typically applied to concrete, but can also be applied to dry plywood or OSB. Care must be taken to keep the product dry until cured. In the summer months, dry time may be 2 to 6 hours. In winter, dry time can be as long as 24 hours or more. The self-adhering product applied at 60 mils wet dries to 45 mils with an elongation of 17%–25% at 70°F. The installed cost is about $2/ft^2$ for a vertical wall surface (Marflex 2014).

Vycor Env, by Grace Residential, is intended for plywood and OSB vertical walls but has not been tested to ASTM 2357 for wall assemblies. This self-adhering product applied at 30 mils wet dries to 15 mils with an elongation of 200%. It can be spray applied or rolled on using a ½-in. nap roller. Care must be taken to keep the product dry until cured. The installed cost is $3–$4/ft^2$; the variance is often due to the height of the home (Grace Residential 2014).

Another FAM made specifically for plywood and OSB is the Tremco Barrier Solutions Enviro-Dri WRB (weather-resistive barrier) for vertical wall applications. Care must be taken to keep the product dry until cured. The product can freeze and will continue to cure, but must be protected from rain and snow. The self-adhering product applied at 15 mils (dries to 12 mils) has an installed cost of about $0.50–$1/ft^2$ when installed on a vertical wall surface. The higher costs are typically seen on homes with complicated designs or heights out of the ordinary (Schremp 2014).

Cost savings could also be realized by using a different method for air/water/vapor control membrane and insulation on the gable end wall. Foil-faced polyisocyanurate with seams sealed could offer insulation as well as the air/water management system thus negating the need for the sheet good membrane. Detailed drawings would need to be supplied to installers in the field to properly align the foil facing and to properly install and flash windows present on the gable wall. Testing in the field would need to be done to be sure this system is doable and cost effective.

4.3 Cost Data for Interior-Applied Air Sealing and Insulation Strategies Provided by Northern*STAR* Industry Partners

The information in Table 5 represents ancillary data provided by Northern*STAR* Industry Partners. It was offered for the team's use during our search for field data from ETMMS projects. It represents full measure costs for interior-applied, roof-only insulation and air sealing retrofits in 1 ½-story homes in both market-rate utility and weatherization programs. Only 10% of the data had accompanying information on specific energy strategies used and project area: Cost per square foot is not included.

Table 5. Average Full Measure Cost for Interior-Applied, Roof-Only Insulation and Air Sealing Retrofits on 1 ½-Story Homes in Market-Rate Utility and Weatherization Programs

Company	# of Projects Provided	Average Full Measure Cost
Center for Energy and Environment	214	$2,260
Neighborhood Energy Connection	3	$2,834
Sustainable Resource Center	23	$2,515

The average full measure costs are quite similar; however, it is not known if the interior attic space in any of the projects was unfinished or finished when the upgrades were applied or if any of the projects represent ice dam mitigation retrofits.

5 Conclusions

The original goal of studying exterior-applied roof insulation, air sealing, and ventilation was to explore a scalable process for reducing energy loss and ice dam formation in 1 ½-story homes in cold climates by improving airtightness. The two previous overcoat reports by the Northern*STAR* team found that air sealing and insulating existing 1 ½-story homes to prevent ice dams continues to be a challenge with no easy method for a scalable approach because of the unique designs and variables found in existing homes. Some contractors promote the overcoat approach as a means to mitigate ice dams, but often use a combined interior/exterior approach for various reasons, including cost, architectural details, finished interior walls, and non-removable exterior claddings.

The first overcoat study showed how some contractors prefer to use the overcoat method to mitigate ice dams but feel costs versus value is not well understood. This study sought to better understand basic costs, additional costs for addressing roof complications, and alternate materials and processes to lower costs of the ETMMS roof-only overcoat approach on 1 ½-story homes in cold and very cold climates.

The roof-only ETMMS process consists of core ETMMS measures consisting of continuous air/water/vapor control membrane, insulation, and ventilation on the roof planes and gable walls, along with air sealing and insulation at the roof/wall connections. Full measure costs for a total project are dependent upon many additional factors such as complexity of the roof planes, architectural features such as dormers and unique trims, removal and rebuild of soffits, roofing material, siding material, and gutters and downspouts.

5.1 What Are the Installation Costs and What Value Engineering Can Be Applied?

The Northern*STAR* team is grateful to Steve Schirber of Cocoon, Inc. and Paul Eldrenkamp of Byggmeister, Inc. for sharing their installed cost data so others may learn and benefit. The core measure costs and full measure costs provided by the contractors represent their styles of work, experiences, vendor relationships, and geographic locations. Costs are provided as a guide but most likely will vary by contractor, team experience, material costs, and location.

The average costs to install the core ETMMS measures on the roof planes, including the air/water/vapor control membrane, insulation, ventilation, and new roof decking, ranged from a minimum of \$10.25/ft^2 to \$11.30/ft^2. Each contractor noted that full measure cost of a project will always be higher and depends on many variables such as soffit removal/rebuild, insulation, and air sealing at roof/wall/floor connections and gable ends, project specific needs, and trim details. When the Cocoon ice dam projects were complete, the full measure costs ranged from \$20–\$30/ft^2 of roof surface area.

When the cost measures associated with ETMMS components were computed for the model home (\$19,476 divided by1,440 ft^2 of roof surface area), a partial measure cost of \$13.53/ft^2 of roof surface area results. Direct comparison to the Cocoon full measure costs of \$20–\$30/ft^2 of roof surface area, however, cannot be made because the model includes ETMMS components only and does not include roof tear off, repair of roof, trim details, roofing material, or gutters/

downspouts. It does, however, provide insight into how the cost of ETMMS components might contribute to the full measure cost of an overcoat project.

The full measure costs for the Cocoon homes and the partial project cost of the model home are significantly higher than the reported full measure range of $3,493 to $11,087 for the Chicago Bungalows (Neuhauser 2012) and the $2,260–$2,834 range reported by the industry partners. This direct comparison is not accurate because the Cocoon and model home data represent exterior-applied insulation, air sealing, and ventilation solutions for ice dams. The new roofing and water management components also account for a significant part of the full measure cost. The ancillary data represent interior-applied air sealing and insulation solutions to reduce energy consumption. Comparing the cost data, however, does provide a look at the cost ranges experienced in the field for roof-only, energy-related solutions on 1 ½-story houses.

When comparing full measure costs for ice dam mitigation projects that are known to the Northern*STAR* team, the $20/ft^2 of roof surface area for the Cocoon St. Louis Park house is similar to the costs reported by contractors participating in the first BA report (Ojczyk et al. 2013a). In that report, full measure costs ranged from $16–$21.74/ft^2 of roof surface area for roof-only, interior-applied ice dam solutions on 1 ½-story homes. The range in project costs illustrates the variety of solutions—whether interior or exterior—to reduce heat loss and prevent ice dams.

5.2 What Components and Techniques Are Available To Minimize Costs

FAMs have become popular as foundation waterproofing and above-grade, vertical wall air/water barriers. FAMs could serve as substitutes to the sheet good product typically used in the exterior overcoat process at a lower cost. Even though these products are available for use today, they have not been approved by the manufacturers for use on sloped planes such as roofs or with long fasteners used in ETMMS.

ETMMS also becomes more cost effective when it is combined with other planned home improvement needs such as new roof material or wall cladding.

5.3 What Construction Methods Will Ensure Effectiveness and Enhance Efficiency?

There is no substitute for experience as a method for ensuring effectiveness and efficiency related to the ETMMS approach. The unique nature of the process imparts a learning curve to a project with a cost that decreases as experience increases. The more opportunities a crew has to follow the ETMMS protocol, the greater the opportunities for innovation that can lead to cost efficiencies as well.

Good communication, detailed drawings, and construction planning are also important for achieving success and keeping costs lowered. It is easier to connect the furring strips to the roof through the wood sleepers and thick insulation layers if the roof framing is mapped when the roof is stripped. The markings of frame location then need to be transferred through the addition of the successive ETMMS layers. Fog and pressurization can be used to evaluate air sealing and verify effectiveness.

5.4 What Lessons Were Learned From Previous Attempts at Exterior Overcoat Application by Some Contractors?

The actual process used to mitigate ice dams in a home is particular to a home and its unique set of existing conditions such as multiple roof planes and gable ends, dormers, architectural details, historic details, finished interior walls and floors, and budget. A roof-only approach using ETMMS is a valued method for mitigating ice dams; however, contractors may have to apply a modified approach.

An understanding of project goals is important for creating the most cost-effective approach. If the goal is to reduce energy use, air sealing and insulation from the interior may be an appropriate solution. If ice dam mitigation is desirable, the ability to air seal, insulate, and ventilate effectively should drive the solution. If interior walls and floors are already finished, an external solution may be the best approach to prevent disruption to the occupants and maximize opportunities for air sealing, insulation, and ventilation.

ETMMS appears to be one of the most expensive options for reducing energy loss. The Cocoon projects, however, illustrate that it can be an effective method to mitigate ice dams. Solving an ice dam problem and preventing the need for restorative work from structural damage may be worth it to clients with reoccurring ice dams as well as for those clients with homes undergoing major exterior upgrades such as new roof cladding, wall cladding, and/or windows.

5.5 Additional Conclusions

The cost data provided by Cocoon and Byggmeister assist the BA program in enhancing outreach potential to professionals. Prior to the research, no data were available to inform professionals about basic costs and procedures to install a roof-only ETMMS strategy on 1 ½-story homes. This information can be used by professionals when weighing solutions to solve moisture issues, energy loss, and ice dam problems.

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Appendix: Solution Center Guide

Guide Title: Roof-Only External Air Sealing and Insulation

Keywords: overcoat, roof, 1 ½-story house, exterior rigid insulation, roof, continuous air and water barrier, ETMMS, ventilation

Climate Zone: All

Construction Types: Existing Homes

Scope: Thermal Enclosure Upgrades for Existing Homes

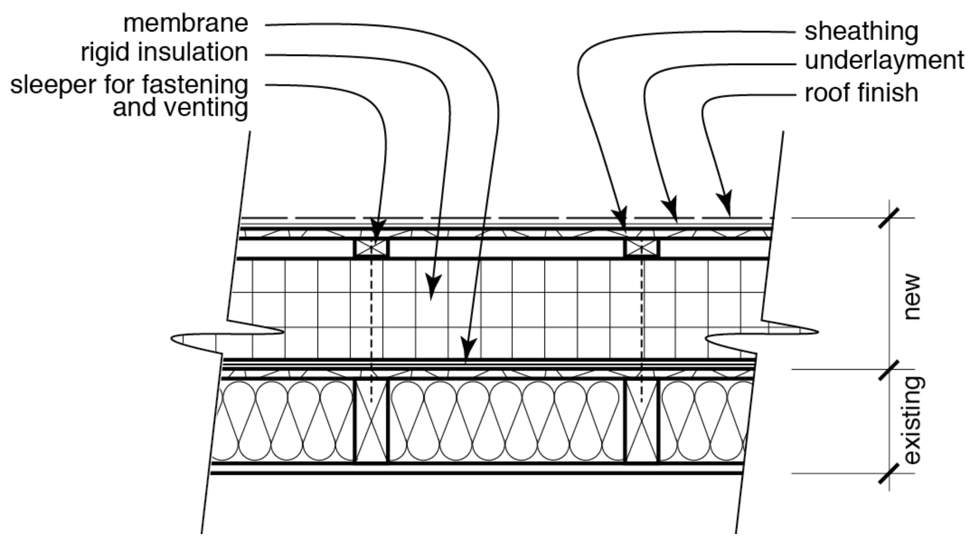

Image Title: The basic components of the ETMMS overcoat process for existing homes.
Image Source: Northern*STAR* Team, University of Minnesota, 2013, Unpublished.
Display Image Filename: NS_basic-components-ETMMS-overcoat-process_TE.jpg

The ETMMS, typically seen in deep energy retrofits, is a valuable approach for the roof-only parts of existing homes, particularly the 1 ½-story home. It effectively reduces energy loss through the building envelope, improves building durability, reduces ice dams, and provides opportunities to improve occupant comfort and health.

This overcoat approach involves installing a continuous air barrier, thermal barrier, and ventilation system on all planes above the attic floor. It is appropriate for homes with conditioned living space in the attic or where there is intent for conditioned living space in the attic. It is a valuable tool for reducing heat loss during heating months as well as ice dams and frost on the underside of the roof deck in cold climates with snow loads. During cooling, an overcoat system can help reduce heat gain and control condensation.

Description
One of the problems many older homes in cold and very cold climates face during winter months is the development of ice dams and moisture damage from frost on the underside of the roof deck. They are particularly a problem in 1 ½-story homes because heat is lost through the building envelope. This is important because many older homes, especially those with 1 ½-story construction, experience ice dams and resulting structural and/or interior damage and increased heating energy use. Many approaches to ice dam mitigation have been in tried in the past, including: (1) interior-applied improvements to insulation and air sealing; (2) roof raking; and (3) heat tapes.

External insulation upgrades are one potential solution to these problems. External insulation can provide a long-term solution to ice dams by providing three key components: (1) reduced air leakage via a continuous air barrier; (2) reduced heat loss via continuous insulation; (3) effective roof ventilation. All are difficult to achieve from the inside when attic space has been converted to finished living space, rafter depth for insulation is shallow, and the roofs are complicated with dormers. Ventilating the roof deck is extremely difficult—if not impossible—from the inside.

The goals of the roof-only ETMMS process are to (1) thoroughly insulate and air seal all the roof planes and gable ends above the ½-story to control energy loss; and (2) improve building durability and occupant comfort.

The following figure illustrates the positioning of the air/water control membrane, insulation, and ventilation as applied to the roof surface area. It also represents the layering when applied to the gable end walls that are finished with appropriate cladding. The fully adhered ice and water control membrane, installed shingle-style, provides robust air control. The insulation is installed in multiple layers with joints offset to improve airtightness and to control convective looping and airflow networks within the insulation layer. All seams are sealed with canned foam. Ventilation is provided by the gap between the insulation and final roof sheathing created by the sleeper.

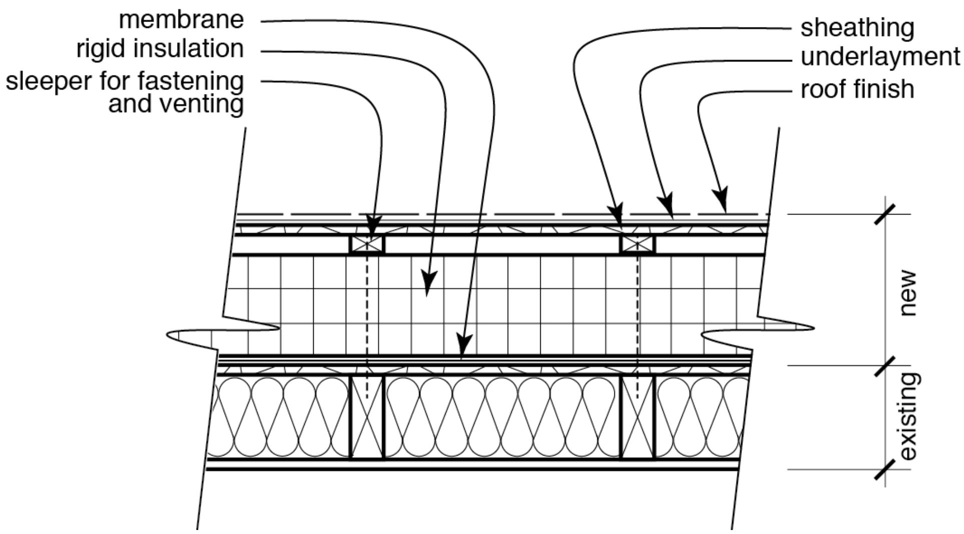

Image Title: The basic components of the ETMMS overcoat process for existing homes.
Image Source: Northern*STAR* Team, University of Minnesota, 2013, Unpublished.
Display Image Filename: NS_basic-components-ETMMS-overcoat-process_TE.jpg

External Insulation

Both XPS (extruded polystyrene) and foil-faced polyisocyanurate are appropriate materials for external insulation that also functions as a drainage plane. See "Taped Insulating Sheathing Drainage Planes" Guide for more information.

How-To

1. Remove all roofing materials down to the existing roof deck. Remove gutters, fascia, and soffit and cut back rafter tails to the existing top plates using a chainsaw approach.

Image Title: Remove gutters, fascia, and soffit using chainsaw approach.
Image Source: Cocoon, 2013, Unpublished
Display Image Filename: NS_remove-gutters-fascia-soffit_TE.jpg

2. Remove roof deck at roof/gable wall connection.
3. Revent existing bath fans and other penetrations out the gable walls to reduce the number of roof penetrations
4. Air seal roof/wall connection at top plates using ccSPF.
5. Air seal roof/gable wall connections from the exterior using ccSPF.
6. Apply membrane primer to roof deck and gable walls. Apply air/water/vapor membrane over the primed roof deck and lap over the exterior walls.

Image Title: Apply air/vapor/water membrane over roof deck and lap over walls
Image Source: Cocoon, 2013, Unpublished
Display Image Filename: NS_apply-membrane-roof-deck_TE.jpg

7. Air seal gable walls from the exterior by wrapping the roof plane membrane over a membrane applied to the wall sheathing on the gable ends. (If the cladding on the gable end walls cannot be removed and air sealing cannot be done from the exterior, the gable wall can be air sealed and insulated from the interior using ccSPF aligning air control layers.)
8. Insulate roof/wall connection with rigid foam.

Image Title: Insulate roof/wall connection with rigid foam.
Image Source: Cocoon, 2013, Unpublished
Display Image Filename: NS_insulate-roof-wall-connection-rigid-foam_TE.jpg

9. Install new soffit framing and sub fascia to accommodate for the additional thickness of the roof and to match the existing architectural style of the house

Image Title: Install new soffit framing and sub fascia.
Image Source: Cocoon, 2013, Unpublished
Display Image Filename: NS_install-new-soffit-fascia_TE.jpg

10. Install two layers of rigid insulation board, seams staggered, over the rubber membrane.

Image Title: Install rigid insulation board over rubber membrane.
Image Source: Cocoon, 2013, Unpublished
Display Image Filename: NS_install-rigid-insulation-over-membrane_TE.jpg

11. Fill seams with low-expanding canned foam. Tape seams using manufacturer-recommended tape per manufacturer instructions.

Image Title: Fill seams with low-expanding canned foam.
Image Source: Cocoon, 2013, Unpublished
Display Image Filename: NS_fill-seams-low-expanding-foam_TE.jpg

12. Install sleepers through the insulation and to the roof rafters with 10-in. screws appropriate for structural connection to allow for continuous ventilation

Image Title: Install sleepers through insulation and to roof rafters.
Image Source: Cocoon, 2013, Unpublished
Display Image Filename: NS_install-sleepers_TE.jpg

13. Attach new roof decking to sleepers.
14. Install roof waterproofing and finish materials over the decking: extend plumbing stacks and follow proper flashing protocol.
15. Install new continuous soffit and fascia venting and insect barrier before gutters are installed.

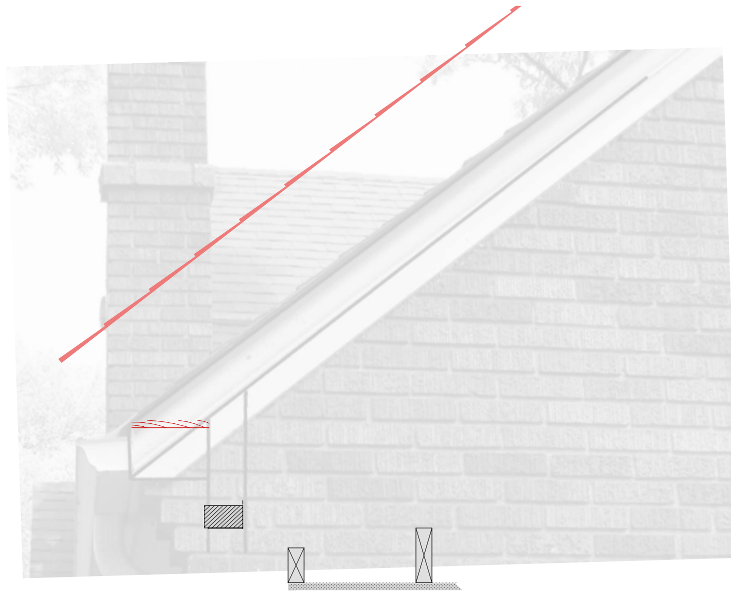

Image Title: Insulation, air barrier alignment, and soffit reconstruction.
Image Source: Cocoon, 2013, Unpublished
Display Image Filename: NS_insulation-air-barrier-soffit-reconstruction.TE.jpg

16. Install roofing materials along with a continuous ridge.

Ensuring Success

Determine if the home is a good candidate for a roof overlay. Considerations include:

- Has the attic space be converted to conditioned living space? Will it be converted to conditioned living space in the near future?
- Are there significant heat loss performance issues such as ice dams?
- Are additional upgrades being considered such as roofing, siding, windows, eaves, and cornice work? ETMMS is most cost effective when the home is undergoing additional and complementary work.
- Can the client afford it?

Allow time for planning prior to construction to address construction issues resulting from unique architectural features, safety concerns that could arise because of airtightness improvements, and sequencing of construction events to ensure home is protected from weather.

- Identify areas affected by elevating roof deck 8 in.

Image Title: Edina Home, Before ETMMS Retrofit
Image Source: Cocoon, 2013, Unpublished.
Display Image Filename: NS_edina-home-before-retrofit_TE.jpg

- Conduct a preconstruction blower door test with infrared thermal imaging to create a baseline for comparing post-retrofit improvements.
- Identify occupant safety and building durability concerns caused by improved airtightness post-retrofit:
  - Combustion safety
  - Occupant and mechanical ventilation
  - Radon.
- Limit roof penetrations by rerouting vents to gable end where possible.
- Sequence tear off and dry-in:
  - Demolish and repair existing roofing materials, roof deck, existing attic insulation.
  - Remove soffits with a chainsaw.
  - Spray foam roof/wall connections.
  - Prime and install air/vapor/water membrane.

Retest the home using a blower door test and infrared thermal imaging after the air/water/vapor membrane has been applied to assess the tightness and identify areas of improvement.

Climate-Specific Factors and Details

A continuous air barrier, thermal barrier, and ventilation system applied externally to all planes above the attic floor can be beneficial to homes in all climate zones.

Training

Presentations
Building America webinar. May 21, 2014. "High Performance Enclosure Strategies: Part I, Existing Homes - Project Overcoat." http://energy.gov/sites/prod/files/2014/05/f16/BA_Webinar_steveschirber_5-21-14.pdf

Architectural CAD Files
None available

Compliance
Local building codes have specific requirements such as the R-value of insulation, fire and combustion requirements, radon mitigation requirements, flood prevention requirements, and requirements for a pest control. Begin by checking with local authorities to ensure that all materials and work comply with local code requirements.

Provide structural engineering, if required, to ensure the home will remain structurally sound with the additional weight from insulation, sleepers, and new roof deck.

More Information
PNNL. 2014. *Building America Case Study Technology Solutions for New and Existing Homes: Cost Analysis of Roof-Only Air Sealing & Insulations Strategies on 1 ½-story Homes in Cold Climates.* Prepared by the Pacific Northwest National Laboratory for the U.S. Department of Energy Building America Program.

Climate Zone: All

Case Study Type: Measure Specific

Construction Type: Existing

PNNL. 2014. *Building America Case Study Technology Solutions for New and Existing Homes: Project Overcoat: Airtightness Strategies and Impacts for 1 ½-Story Homes.* Prepared by the Pacific Northwest National Laboratory for the U.S. Department of Energy Building America Program.

Climate Zone: All

Case Study Type: Measure Specific

Construction Type: Existing

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