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Project Overcoat—An Exploration of Exterior Insulation Strategies for 1½-Story Roof Applications in Cold Climates

Cindy Ojczyk, Garrett Mosiman, Pat Huelman, Tom Schirber, Peter Yost, and Tessa Murry
Northern*STAR*

April 2013

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Prepared for:

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Office of Energy Efficiency and Renewable Energy

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Unless otherwise noted, all tables were created by NorthernSTAR.

Definitions

BA	Building America
BSC	Building Science Corporation
Btu	British thermal unit
cfm	Cubic feet per minute
DER	Deep energy retrofit
DOE	U.S. Department of Energy
EIFS	Exterior insulation finishing system
EPS	Expanded polystyrene
ETMMS	External thermal moisture management system
FMS	Force measuring sensor
ft^2	Square foot
HRV	Heat recovery ventilator
MLS	Multiple Listing Service
NYSERDA	New York State Energy Research and Development Authority
PERSIST	Pressure Equalized Rain Screen Insulated Structure Technique
pc/L	Picocuries per liter
REMOTE	Residential Exterior Membrane Outside Insulation Technique
SIP	Structural insulated panel
SPF	Spray polyurethane foam
Sqft	Square feet
XPS	Extruded polystyrene

Executive Summary

Interior approaches to energy loss and ice dam mitigation have been favored by contractors and homeowners because of the perceived lower cost and ease of application. Interior approaches to preventing energy loss through roofs can be effective if detailed protocols for aligning air barriers and applying adequate levels of insulation are followed. The rise in winter-storm-related insurance claims in 2010, however, indicates that a more reliable approach is needed. Millions of older homes with complicated roof structures, like the 1½-story Cape Cod, remain vulnerable to heat loss and ice dams caused by hurdles that prevent thorough insulation and air sealing from the interior.

The Northern*STAR* Building America Partnership team was interested in exploring more robust solutions for older homes at risk for heat loss and ice dam formation. This three-part exploration was focused on identifying an exterior approach for the roof portion of 1½-story homes with the potential to provide cost-effective, long-term, scalable solutions. In part one, the team conducted a literature review to examine four exterior insulation and air sealing techniques to determine which solution appears most effective. In part two, a limited study of the Multiple Listing System in the Minneapolis area was used to broadly estimate the number of existing homes in cold climates that could be improved through an exterior insulation approach. In part three, the Northern*STAR* team interviewed a sampling of contractors who have participated in ice dam mitigation projects to gain baseline knowledge on how they sell, design, and construct ice dam solutions.

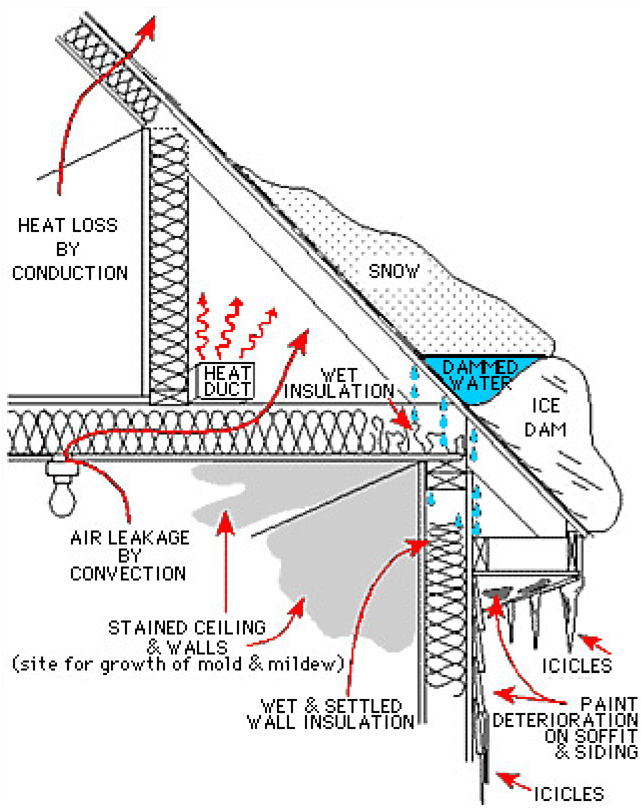
This exploratory study found that research favors an exterior approach to deep energy retrofits and ice dam prevention in existing homes using the external thermal moisture management system technique. But this technique has been mainly documented for whole-house deep energy retrofits, leaving a void in data for roof-only applications and durability, constructability, and cost. Contractors interviewed for this report indicated an understanding that exterior approaches are most promising for mitigating ice dams and energy loss and reported being able to sell these strategies to homeowners.

Results from this research can help direct future Building America research activities in efforts to create information for professionals, homeowners, and insurance companies. Such information will allow them to make decisions about roof-related energy improvements and ice dam repair and prevention.

1 Introduction

A key durability concern for existing homes in cold climates is ice dams resulting from heat loss through the roof. In areas of the country that experience snow accumulations, 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, and further exacerbation of rot and water damage. In addition, ice dams pose safety risks from falling ice, structural collapse of roof overhangs, and shearing of deck assemblies from ice and snowfall.

Figure 1 from Larson and coauthors (2010) demonstrates how heat loss can promote ice dam formation and reduce building durability as well as energy efficiency.



Source: Larson et al. 2010

Figure 1. How an ice dam forms

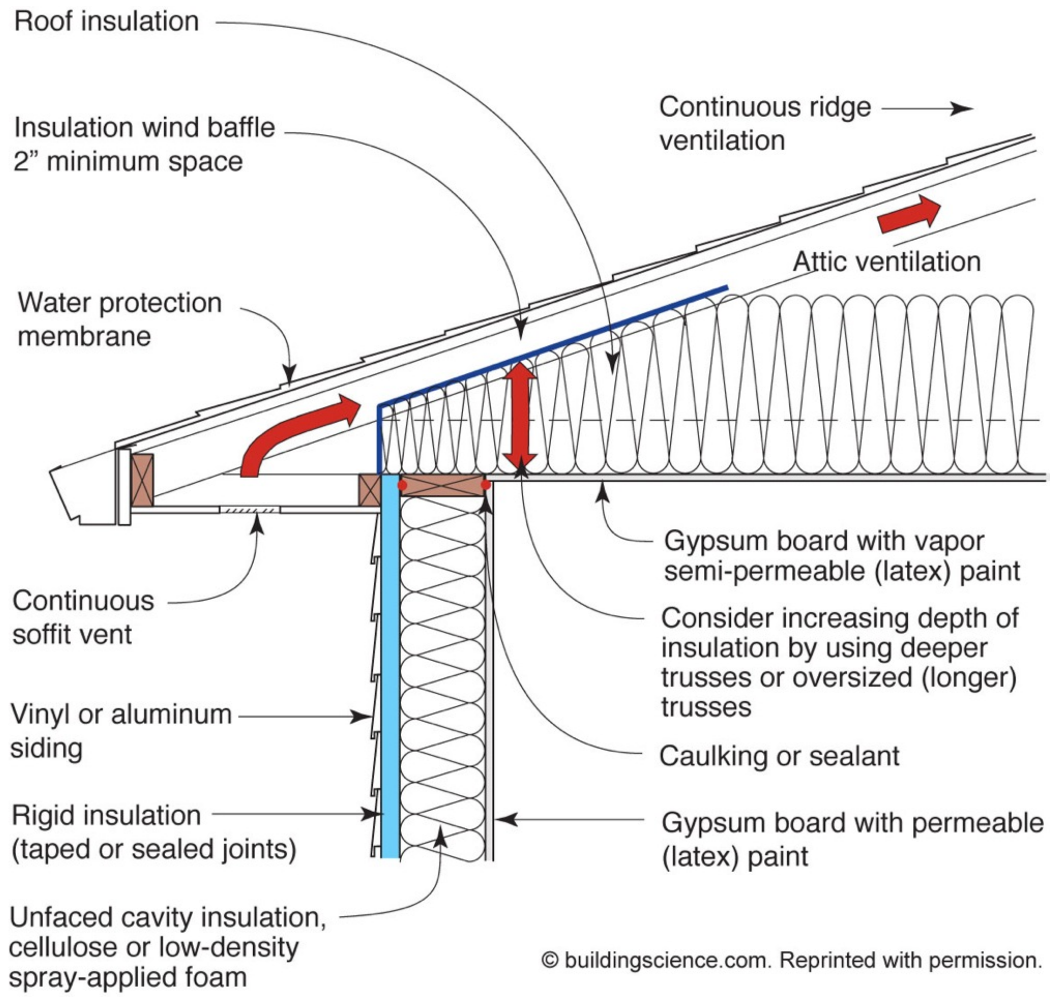
O'Rourke and colleagues (2010) found the size of an ice dam to be a function of snow load, roof R-value, indoor temperature, and effective eave to ridge distance. Complex roof geometries such as roof valleys and dormers, by adding surface area opportunities for snowmelt, have a further impact on the size of the ice dam. The horizontal extent of the ice dam was found to be a function of the slope of the roof, with low-slope roofs exhibiting greater horizontal extent. As horizontal extent increases, the potential for water seepage and wetting of interior surfaces also increases. The application of this research is limited because it only studied the impact of indoor temperature on ice dam formation. Estimating that the impact of air leakage would exacerbate predicted ice dam formation, the Northern*STAR* team recommends expanding the research to include the impact of air leakage.

Ice dams can require expensive removal or can lead to expensive repair. This problem becomes an even greater frustration when homeowners who have invested in energy efficiency improvements to address ice dams one year continue to experience heat loss and ice dam formation in subsequent years. There are limited data to calculate the extent of residential ice dam re-formation after an attempted mitigation, but a report by Lstiburek (2008) and anecdotal reports in the media and within the building industry indicate that it does occur frequently.

According to the Insurance Information Institute (2012), losses resulting from water damage and freezing have increased significantly from 14.60% of all claims in 2005 to 23.7% in 2009. These claims were the second most claimed loss behind wind and hail. Iowa Insurance Institute Communications (2011) reported that winter storms accounted for 7.4% of catastrophic losses nationwide from 1991 to 2010, or an average of $1.3 billion per year. In 2010, more than $1 billion in claims for damage caused by winter storms were filed on the East Coast alone (Air Worldwide 2011).

It is difficult to isolate the amount of homeowner claims resulting from ice dams because that information is part of total winter storm claims. But it can be assumed from a review of insurance company websites that ice dam prevention is an important issue. Most insurance companies offer ice dam prevention information on their customer websites (State Farm Insurance 2012; Insurance Institute for Business and Home Safety 2012). These websites, however, offer generic information on ice dam formation, but little detailed information on proper prevention strategies.

Energy research has shown that improving the building envelope can have a significant impact on comfort, building durability, and energy bills. The question is how to properly incorporate energy strategies without compromising the integrity of the building envelope. The *Building America Special Research Project: High-R Roofs Case Study Analysis* (Straube and Grin 2010) states that the consensus in the research community is that fully vented, pitched attic assemblies are the lowest cost and provide the highest R-value, most durable roofs in all climate zones when no ductwork or major air leakage are above or in the ceiling plane. Figure 2 demonstrates the strategies that must be combined to achieve optimal R-value and durability with this interior approach.



Source: Straube and Grin 2012

Figure 2. Fully vented pitched attic assembly for highest R-value and durability

Figure 2 highlights the insulation, air sealing, and ventilation strategies considered optimal for fully vented, pitched attic assemblies, but it is truly focused on new construction where the strategies can be incorporated into a home design before construction. Additionally, these strategies are relevant only when the attic will remain unconditioned and will not be used for living space.

Existing homes do not always have the flexibility of design necessary for optimizing energy efficiency and durability because of barriers to effective air sealing, insulation, and ventilation. One hurdle in existing homes is the inability to change the truss structure to make it deeper or longer (refer to Figure 1), which prevents the application of appropriate insulation depth. Lack of industry consensus on when roof venting should be employed may lead to the creation of unvented roof decks that should be vented. The presence of ceiling penetrations, such as those from recessed lighting, limits opportunities for effective air sealing. If the trio of strategies cannot be done extremely well, top building researchers have recommended an exterior insulation overcoat approach to prevent ice dam formation (Lstiburek 2008) in existing homes with unconditioned attics.

Existing homes where homeowners wish to live in the attic space pose additional challenges to insulation, air sealing, and roof ventilation necessary to prevent ice dam formation. Finished walls, shallow rafter bays, roof pitch, major and minor valleys created by dormers and architectural details, lack of raised heel energy truss, obstacles, and penetrations all encumber the application of the trio of strategies, indicating that an exterior overcoat approach may be the best solution for energy efficiency and ice dam prevention.

The Northern*STAR* Building America Partnership team was interested in exploring more robust exterior roofing solutions for existing 1½-story homes. This three-part exploration was focused on identifying an exterior approach with the potential to determine cost-effective, long-term, scalable solutions. In part one, the team conducted a literature review to examine four exterior insulation and air sealing techniques used in new construction, deep energy whole-house retrofits, and roof-only applications. The literature review was undertaken to determine which solution appears most effective in preventing heat loss through the roof and ice dam formation. The following exterior insulation strategies have been used in the cold-climate markets for energy improvements and ice dam mitigation and were investigated in this exploratory research:

- External thermal moisture management system (ETMMS)
- Spray foam
- One-sided structural insulated panel (SIP) overlay (often called a "retrofit" panel)
- Over-roofing.

Figure 3 depicts the basic details for the ETMMS roof overcoat approach.

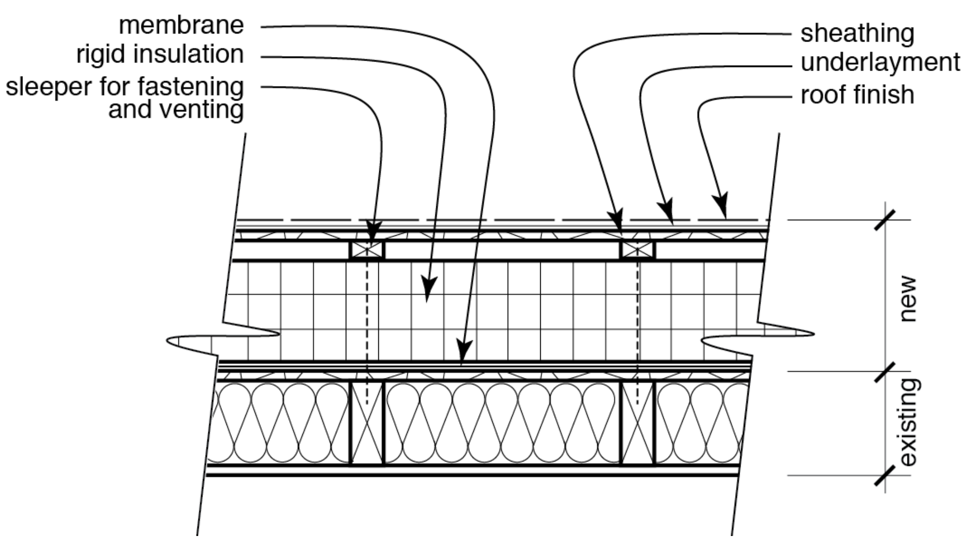


Figure 3. Details for ETMMS roof overcoat approach

The figure demonstrates the air/vapor membrane layer between the existing roof decking and the rigid insulation. Ventilation is designed into the system using sleepers attached through the insulation. Roof sheathing and underlayment are similar to standard roofing practices.

Figure 4 demonstrates the layering of the materials in the ETMMS approach.

Figure 4. Details of ETMMS exterior overcoat retrofit on 1½-story home

(Courtesy of Cocoon)

Figure 5 is similar to the ETMMS rigid insulation approach, but closed cell spray foam is substituted for the rigid insulation.

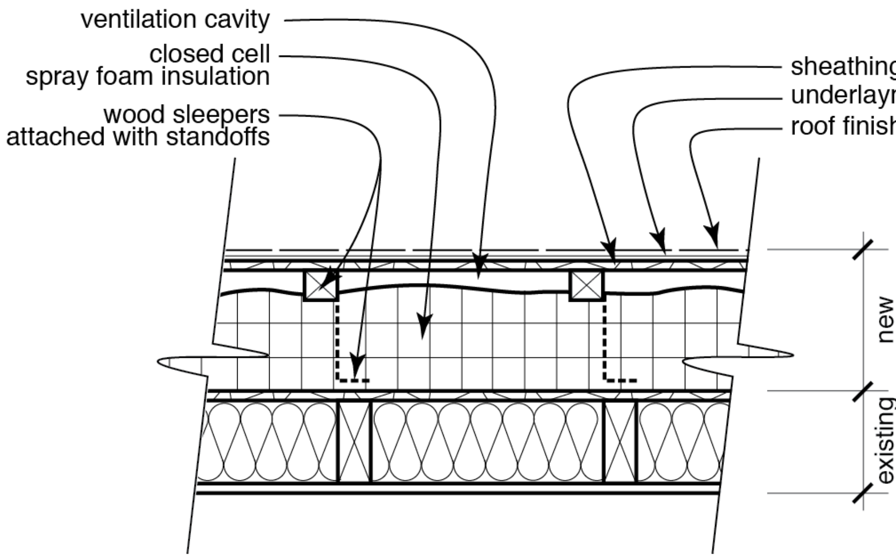


Figure 5. Details of spray foam exterior roof overcoat approach

Figure 5 demonstrates the use of wood sleepers attached with standards to the existing roof framing to create a cavity that contains a continuous layer of closed cell foam. Care must be taken to ensure that the foam does not reach the front edge of the sleeper. This maintains a natural ventilation area between the face of the foam and the new roof sheathing.

Figure 6 shows the SIP retrofit panel where the panel is manufactured with a structural panel on one side only and the exposed foam face is placed directly atop an air barrier applied over the existing roof decking. The sheathing of the SIP provides the roof decking for the new roof material. Figure 6 also depicts an unvented, hot roof application that is commonly seen in the marketplace.

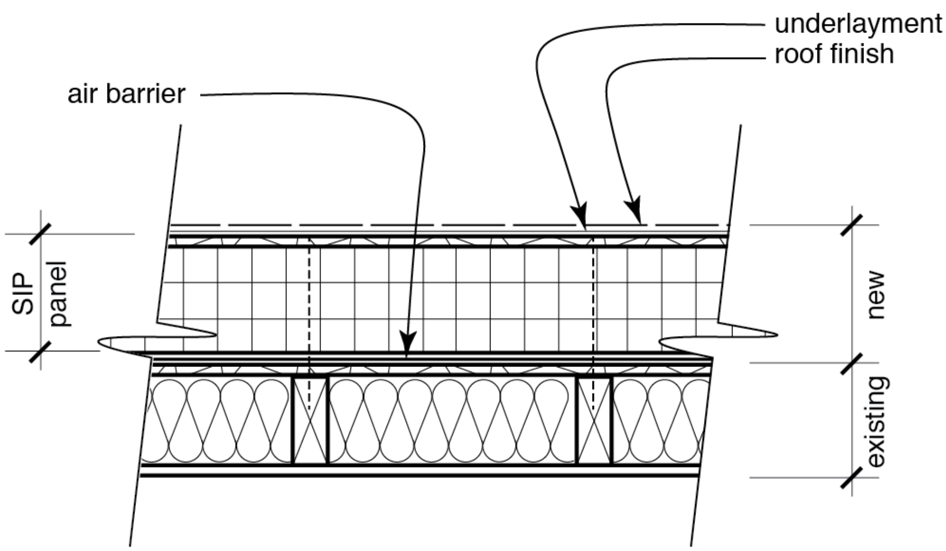


Figure 6. Details of an unvented SIP retrofit

Figure 7 illustrates a vented SIP retrofit type that is being created by a few SIP manufacturers in the marketplace. Creating grooves in the foam may reduce insulation value of the complete system but does allow some heat to escape between a soffit and roof ridge.

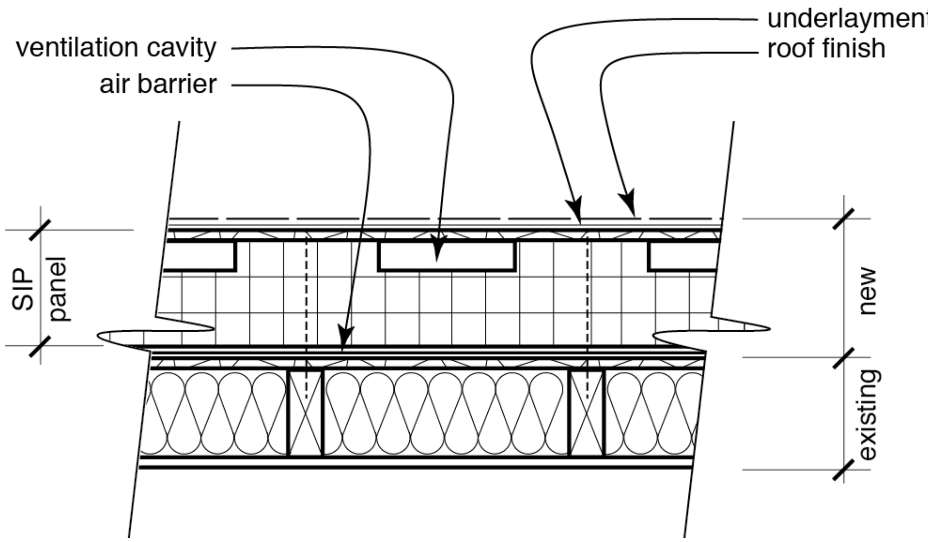


Figure 7. Details of a vented SIP retrofit

Figure 8 illustrates an over-roofing approach in which a vented roof insulated with batt insulation is applied directly to the existing roof decking.

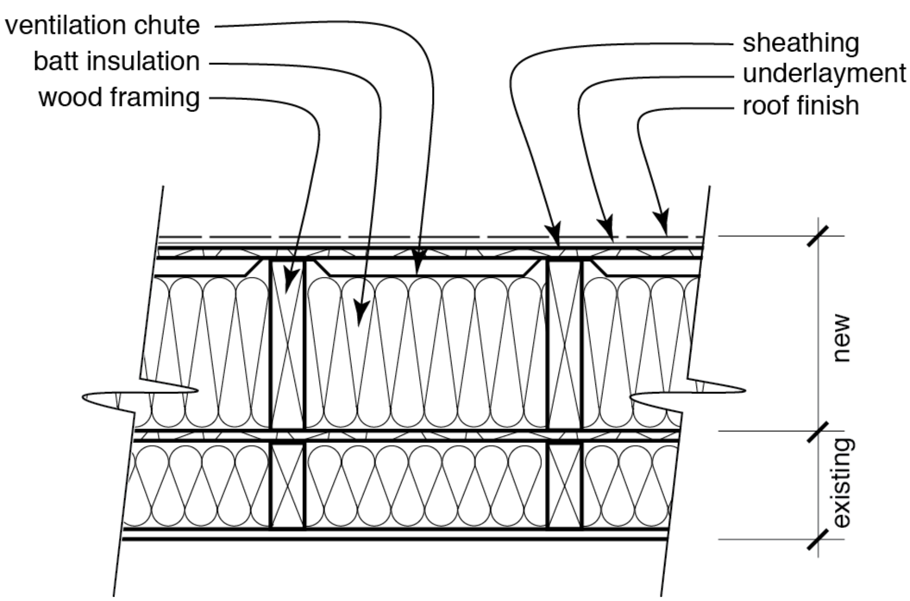


Figure 8. Details of an over-roofing approach

Because of the added wood sheathing and materials associated with these overcoat strategies, cost is a large barrier in bringing any of these to market in a scalable manner. For homeowners fighting recurring ice dams or those seeking to expand living space into an unfinished attic, however, the combination of energy improvement and ice dam prevention may be the incentive that overcomes the cost. Alternative materials were also investigated whenever possible to uncover opportunities to lower overcoat costs and to make them more competitive with interior insulation.

In part two of the exploratory study, the Multiple Listing System (MLS) in the Minneapolis area was used to roughly estimate the number of existing homes in cold climates that could be improved through an exterior insulation approach.

In part three of the study, a sampling of contractors that have participated in ice dam mitigation projects were interviewed to gain baseline knowledge on how they sell, design, and construct ice dam solutions. The Northern*STAR* team was also interested in learning about the ease of installation of each exterior insulation strategy on different 1½-story roof typologies. Figure 9, Figure 10, Figure 11, Figure 12, and Figure 13 represent the most common 1½-story roof typologies and were used in interviews with the builders.

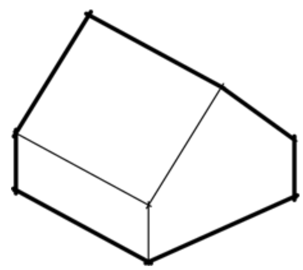


Figure 9. Two-plane, two-gable roof

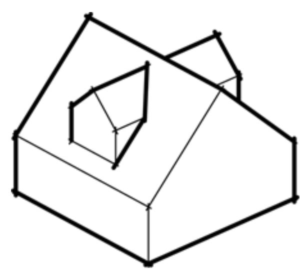


Figure 10. Two-plane, two-gable roof with gable dormers

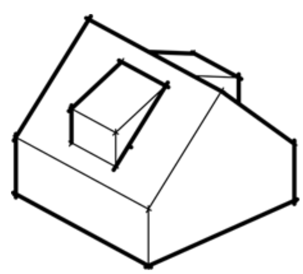


Figure 11. Two-plane, two-gable roof with shed dormers

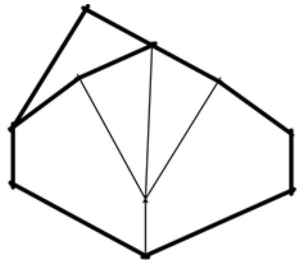


Figure 12. Four-plane, three-gable roof

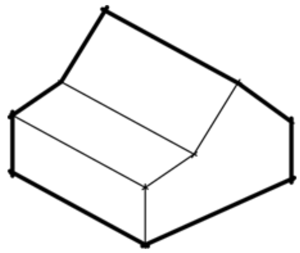


Figure 13. Three-plane, two-gable roof

Another common roof typology, not illustrated here, is a two-plane, two-gable roof with both gable and shed dormers.

In addition to predicting how easily each exterior insulation type can be installed on the different roof typologies, it was important to learn if rooftop obstacles such as valleys, chimneys and vents, skylights, soil stacks, and architectural/structural details at the eave presented hurdles to the overcoat approach. Figure 14 illustrates the variations in obstacles and roof typology from house to house.

Figure 14. Established neighborhood in Minneapolis displaying various roof typologies and obstacles

(photo from maps.google.com)

Although energy efficiency and ice dam prevention were critical elements to investigate, the Northern*STAR* team explored other key performance attributes of the various exterior overcoat strategies during the literature review and contractor interviews. Durability was considered by evaluating potential impact on interior and exterior moisture control and moisture storage and drying potential. Indoor environmental quality was explored by evaluating the impact of changes to the building envelope and potential combustion safety issues. Team members reviewed the literature for information on indoor air quality issues potentially linked to exterior materials and installation methods. Constructability was assessed by evaluating exposure time, subcontractor skill versus technical requirements of installation, and material availability. Affordability was investigated by comparing insulation material costs as well as costs with and without new roofing materials, where possible. Additionally, pre- and post-assessment opportunities for evaluating the feasibility of the exterior overcoat method were explored.

2 Literature Review of Four Exterior Roof Insulation Strategies

A large body of research exists to define the strategies for making new homes more energy efficient, durable, and cost effective. Usually the strategies encompass a whole-house, systems approach that looks at the integration of design, materials, and installation. The Building America (BA) Builders Challenge Program and the Environmental Protection Agency's ENERGY STAR Program are just two examples where integrated design is used to maximize overall performance of new homes and deliver energy savings of 20% or more. Strategies such as SIPs, exterior insulation finishing system (EIFS), and ETMMS seek to maximize energy efficiency through unique building envelope designs such as reduced thermal bridging (SIPs) and insulation located on the exterior of the building envelope (EIFS and ETMMS). Several departments at the University of Minnesota have worked directly with the ETMMS to test this whole-house overcoat system on 24 affordable townhomes in one project and 4 single-family homes in another project.

Although the lessons learned from new homes can offer valuable insight into potential strategies for existing homes, the opportunities to address whole-house improvements or even the complete building envelope at one time are limited and not yet practical at a scalable level. The deep energy retrofits (DERs) documented by the New York State Energy Research and Development Authority (NYSERDA) highlight the extra costs that can be incurred when existing materials are removed to ready a structure for an upgrade or preconstruction testing indicates additional measures for energy and occupant safety (Pedrick et al. 2010). Roof decks, sheathing, framing, and sill plates may need repair or replacement if they have experienced water damage. Windows and doors with lead paint need to be addressed according to new regulations. Large obstacles, such as chimneys, may need to be removed. New siding, roofing, and mechanical equipment add additional costs above the energy improvement. The four NYSERDA whole-house overcoat projects were able to achieve a commendable 69% to 81% reduction in air leakage, but the project costs, which include implementation of deferred and critical repairs along with the deep energy measures, ranged from $96,200 to $144,000.

Researchers continue to examine whole-house DER strategies and ways to reduce costs. Energy improvement for existing homes has been focused on cost-efficient "packages" of options. When installed in existing homes, these packages produce energy savings of 15% or more, motivating a homeowner to action with improved return on investment and comfort. The BA document *Energy Savings Measure Packages: Existing Homes* (BA 2011) uses the Building Energy Optimization energy modeling software to predict energy savings from packages of strategies applied to a reference home design in a variety of climates.[1] A contractor or homeowner can use the information to choose strategies most likely to produce various levels of energy savings for their particular home, geographic location, and fuel type. The strategies listed, however, are limited to sealing air leaks and adding additional ceiling insulation from the interior. They do not address exterior roof retrofit options for problematic attics (those that cannot completely meet the trio of strategies to prevent ice dam formation).

There are also countless magazine and Internet articles, websites, and blogs on the methods for improving energy efficiency of existing homes through roof and attic strategies. Much of the

[1] For more information on the Building Energy Optimization software, see http://beopt.nrel.gov/

information is coming from field experience of individual contractors, code mandates, manufacturer marketing information, and industry experts. Even though some of the information is based on building science principles and new construction best practices, the lack of consistency in approach, as well as the lack of climate-specific, research-supported data, presents confusion in the marketplace.

No building code for existing homes requires a test-in/test-out process to determine if the home has been left in a safe manner for the occupants or if the measures were installed to perform as designed, so little attention to safety and long-term performance is required of product manufacturer, distributor, installer, or homeowner. Yet research-supported guidelines, such as *Attic Air Sealing Guide and Details* (Lstiburek 2010), stress the importance of understanding changes to the home as a result of air sealing techniques. Occupant safety needs to be considered along with energy design.

To begin the process of developing research-based packages of solutions for roof energy loss and ice dam prevention in existing homes, the NorthernSTAR team focused this exploratory study on 1½-story homes with conditioned living space on the upper floor. This type of housing was chosen because it is a common fixture in cities and towns in cold climates and finding a cost and energy effective solution can affect millions of homes.

Most 1½-story homes were built in an era when energy efficiency was neither sought nor understood. Homeowner desire to expand living area into unused attic space, however, has resulted in less than optimal conditions for energy efficiency, comfort, and long-term durability. This house type has been constructed with a variety of rooflines that can be simple or complicated. There are older 1½-story homes (from the 1950s) that were built with finished ½-story spaces and have similar issues. One and one-half story homes suffer from frequent ice dams because of one or more shortcomings, including the following:

- Difficulty in adequately insulating vaulted ceilings with shallow rafter depths
- Difficulty in 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 in properly venting the roof deck with multiple valleys
- Roof obstructions and penetrations such as chimneys, vent and soil stacks, and skylights
- Failure to maintain air barrier continuity at the wall to roof transition at soffit
- Failure to maintain air barrier continuity at the roof to wall transition at dormers

In addition to homeowners attempting to address ice dams with increased insulation and air sealing on the inside, many have also tried heat tapes, heat panels, and metal snow/ice belts at the eaves, full replacement standing seam metal roofing, de-icing materials, and hand raking the eaves. Although these methods can reduce the risk of ice dam formation, they do not attempt to improve the energy efficiency of the home. Their effectiveness also decreases when melting or removing the snow becomes complicated by frequent snow events and accumulations.

The roof "overcoat" concept follows principles developed for new construction building envelope overcoat methods. Examples are the Canadian whole-house overcoat method known as the Pressure Equalized Rain Screen Insulated Structure Technique and the Alaskan wall-only overcoat method known as REMOTE (Residential Exterior Membrane Outside Insulation Technique). In these systems, a continuous air, moisture, and thermal barrier is applied on the outside of the building envelope for improved overall performance. The continuous insulation promotes a reduction in thermal bridging that could further reduce energy consumption.

2.1 External Thermal Moisture Management System

A study by Building Science Corporation (BSC) for BA on high R-value roofing assemblies for new construction indicates that the exterior overcoat approach to roofing can also be applied in retrofit situations (Straube and Grin 2010). The approach promoted in the study for cold climates includes unvented, R-60 roof insulation achieved by combining two layers of 2-in. rigid polyisocyanurate foam on the exterior of the roof sheathing with netted fibrous fill blown into the rafter bays. Figure 15 presents the complete details.

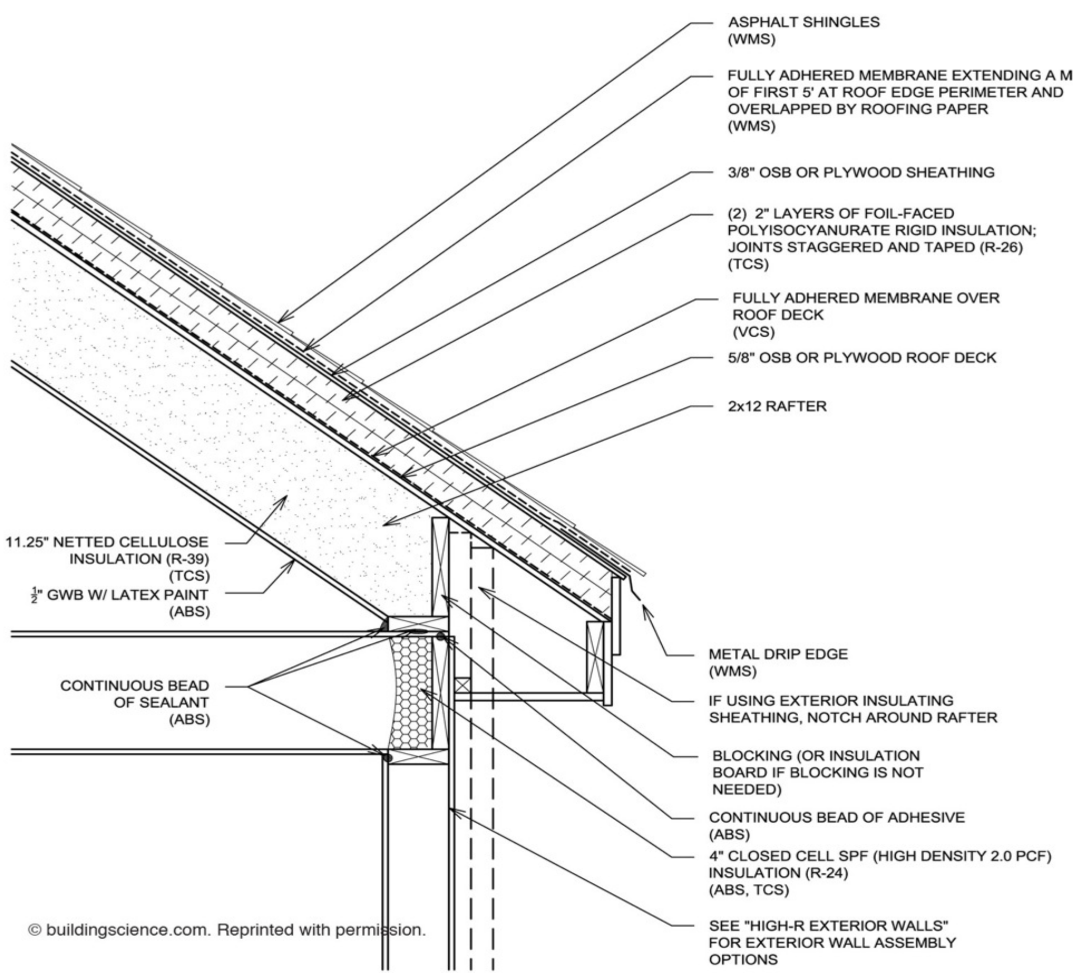


Figure 15. Exterior overcoat approach for roof retrofits

BSC has created numerous case studies of DER projects in which a whole-house overcoat, not just a roof overcoat, process was undertaken. But valuable information for roof retrofits can be understood through examples. Lstiburek (2011) outlines the process of upgrading a 1½-story Cape Cod house built in 1953. The roof was fairly simple in that the shed dormer on the back of the house was increased during the remodel to encompass the whole width of the building and add living space for the homeowners. There were no overhangs on the roof, which proved to be both good and bad. The lack of overhangs made the process of aligning the air barrier and insulation of the walls to the roof easier. The lack of overhangs, however, led to extensive water damage to the wall sheathing (hidden behind the vinyl siding) that needed to be fixed before energy improvements could be installed. A continuous air barrier was adhered to the new wall and roof sheathing. Two 2-in. layers of polyisocyanurate, seams staggered and sealed, were applied over the wall and roof air barrier. High-density spray foam was added to the rafter bays to yield an R-60 roof. The roof was unvented. The Building Energy Optimization analysis of the applied strategies indicated a source energy use savings above 50%.

BSC was involved in the DER of an original Sears Roebuck home, a 3,600-ft^2, four-square, two-story home with a finished attic (Pettit 2009). This process was similar to the 1½-story home retrofit, featuring a whole-house overcoat with two 2-in. layers of polyisocyanurate, seams staggered and sealed, over the air barrier. Again, high-density spray foam was added to the rafter bays, yielding an R-60 unvented roof. The roof of this home, however, was much more complicated than the previous one. The hip roof was interrupted by four hip dormers and deep overhangs. The existing rafter tails were extended and the soffit widened to accommodate the exterior insulation. The large overhangs were detailed with crown molding to accommodate the extra thickness of the exterior foam. Gas utility costs after the retrofit indicated that the whole-house retrofit had been successful; gas usage was reduced by nearly two-thirds. Figure 16 illustrates the details for the overcoat process on the home. Note the removal of the existing attic flooring at perimeter to allow for installation of spray polyurethane foam (SPF) to seal the top plate and align the insulation layers of the roof and wall.

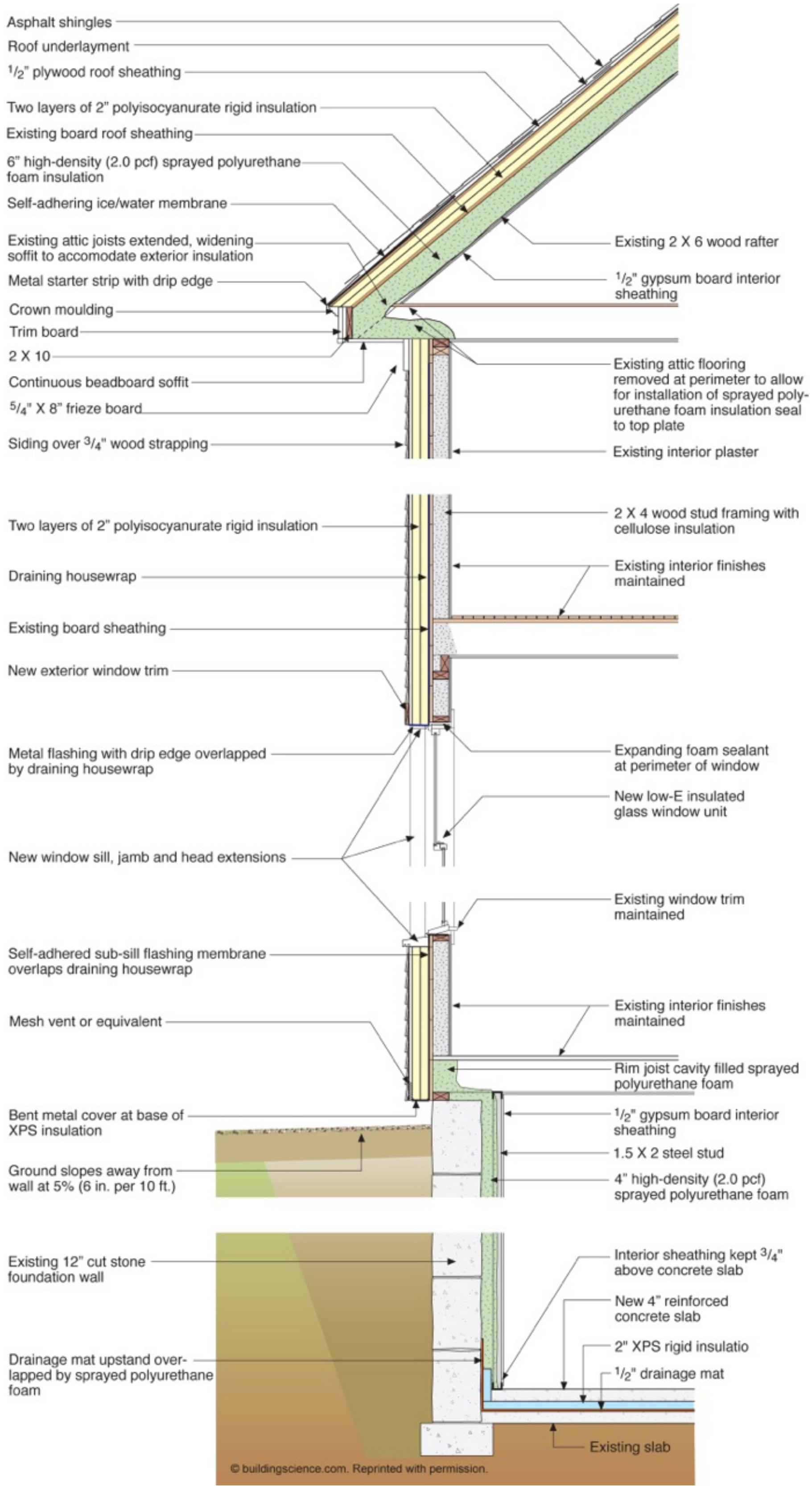


Figure 16. BSC Sears Roebuck house DER details

To develop guidelines for other users of the exterior overcoat strategy, BSC worked with the BA to create comprehensive design and installation details for integrating exterior moisture management and insulation on wall assemblies for DERs (BSC 2009). Drawings include window and door head/jamb/sill/trim, exterior light fixture, electric box, and vent pipe/duct penetration details. Installation sequences for windows and doors are also included.

The BSC information provides guidance on creating whole-house overcoat retrofit assemblies with unvented roofs, which the authors call “compact roofs” (BSC 2009). Researchers at BSC, however, have noted the necessity of venting the upper roof deck in certain situations (Lstiburek 2008). If the snow load is less than 50 lb/ft² and the thermal resistance is greater than R-50, the compact roof can be used. If the ground snow load is greater than 50 lb/ft², the roof should be vented. As the snow load increases, so does the R-value of the snow, insulating the roof deck from above and elevating its temperature above freezing.

Venting the upper roof deck may also be necessary when overhangs are present. Wall claddings can absorb solar radiation and release heat that can get trapped under the overhang. This heat, even though produced on the exterior of the building, can melt snow and result in ice dam formation. The vented air space allows the roof deck to be cooled. Figure 17 shows the vented compact roof.

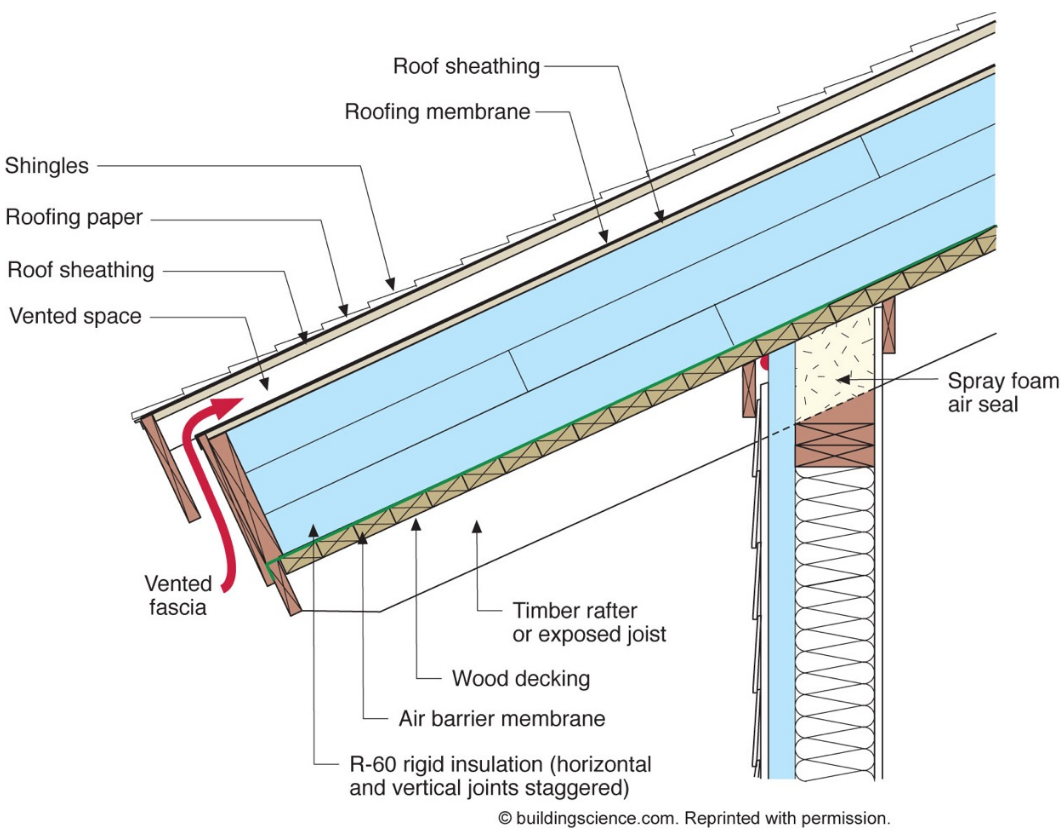


Figure 17. Venting a compact roof to prevent ice dam formation

A small case study from the University of Alaska Southeast (George 2012) found that adding 10.5 in. of extruded polystyrene to the exterior of the roof (no other energy strategy employed) of a home built in 1930 resulted in an air leakage reduction from 4,897 cfm to 691 cfm and a Btu per hour reduction of 70,422 Btu/h to 36,791 Btu/h. The total change went from 27.7 Btu/h/ft^2 to 14.5 Btu/h/ft^2 (both at winter design temperature).

The NYSERDA (Pedrick et al. 2010) DER case studies present whole-house overcoat strategies for four existing homes that follow a similar assembly process as BSC. The layering of materials consisted of a water resistive ice and water shield over the sheathing, two layers of 2-in. polyisocyanurate foam with the edges staggered and sealed, and ½-in. nail base material over the foam to anchor the siding and roofing materials. Roof ventilation was included if there was a high exposure to wind-driven rain, a heavy snow risk, or a complex roof typology. A roof was left unvented if the building envelope was considered airtight, no interior vapor barrier was present, and the roof insulation value was a true R-40. Successful implementation of the overcoat process was driven by comprehensive installation drawings included in the report (Pedrick et al. 2010).

The Cold Climate Housing Resource Center in Fairbanks, Alaska, promotes an exterior wall overcoat system using the REMOTE process. REMOTE is an insulation and moisture management system applied to the exterior of a house wall system that is combined with a conventional, unconditioned attic. Although the process itself does not address roofs, the REMOTE manual (Cold Climate Housing Research Center [CCHRC] 2009) contains numerous detailed drawings and methods for installation of various cladding systems including stucco and lap siding, cladding systems that might be present on the dormers of 1½-story homes. It also includes details on working around obstacles such as windows, decks, bays, and cantilevers, some of which may be present in the upper level of a 1½-story home. The manual does include a short disclaimer on using REMOTE for retrofit situations. It urges caution and consideration on a case-by-case basis because of the limited opportunities to align the exterior moisture management system with the interior vapor barrier system and to apply adequate insulation.

As a follow-up to the REMOTE manual and numerous inquiries from Alaskan property owners, the CCHRC (Craven and Garber-Slaght 2012, 2010) has been conducting laboratory wall studies. The goal of these studies is to understand the effects of varying levels of interior and exterior insulation combined with exterior vapor retarder of the REMOTE wall system in the presence of existing interior vapor barrier. These investigators found that the presence or absence of an interior vapor barrier in the local climate was not of great significance if there was thick exterior insulation—when 65% of the total wall R-value was to the exterior—even when the interior vapor barrier was not perfectly applied.

2.2 Structural Insulated Panels

There is a growing use of SIPs for roof retrofit applications. SIP manufacturers are also modifying their products by removing one layer of sheathing so the foam face can be applied to existing roof sheathing. These revised panels are often called nailbase panels or retrofit panels. In response, classes are available to teach proper installation methods, including effective air sealing, along with post-construction air quality and combustion safety. One example is an upcoming SIP school class where the nailbase panel is used for roof overcoat retrofits (SIPschool.org 2012).

A simple example of a DER using SIPs was documented on a one-story home. The SIPS roofing (12¼ in. at R-60) and walls and exterior expanded polystyrene foam foundation insulation enabled a Massachusetts home to achieve a 70% energy reduction (R-Control 2011).

2.3 Over-Roofing

No documented research could be found for over-roofing as a means of improving energy efficiency or for ice dam remediation.

2.4 Spray Foam

The internet is filled with spray foam companies and contractors offering their products and services as solutions for energy inefficiency and ice dam problems. A homeowner uneducated in building science would have a difficult time separating the fact from the fiction because so many websites claim they are the ones to offer the solution. As noted in Section 1, fixing ice dams from the interior may or may not be successful. Problematic roof structures may limit the ability to effectively apply the trio of solutions—insulation, air sealing, and ventilation—especially in 1½-story homes and homes with cathedral ceilings.

Research on the commercial/industrial building industry indicates that SPF is used quite frequently on the exterior of flat roof systems to overcoat existing roofing. Two-pound closed cell foam has an R-6.5 per inch. Three-pound density foam used frequently at the commercial building level has an R-7.14. Costs were estimated from \$2.50/ft^2 installed (Kohls Foam Systems 2012) to \$5.00/ft^2 installed (Tucker and Knowles 2012). An elastomeric coating or gravel is used over the dried foam for added durability and solar protection.

One research report (Lstiburek 2011) did discuss the use of SPF as exterior insulation for wall assemblies. The initial focus was for use behind brick walls. Attention to detail is critical for successful implementation. Windows and doors require a transition assembly between the glazing systems and the wall assembly similar to that of an extended "buck" to ensure that the window or door can be removed if needed instead of being integrated with the foam. Design details show a window filet made of SPF that is applied prior to the rest of the foaming to prevent gaps at the junction of the buck and the wall foam. Brick works well because installation naturally requires masonry ties and drainage planes. The gap between brick and foam accommodates the unevenness of the foam. Other claddings will require some type of furring system that will maintain a level surface for installation. The downside to a furring system is it can reduce R-value because of thermal bridging from furring to sheathing. This is most true for "z" girt systems. There are, however, some manufactured and field-implemented systems (fasteners with stand-offs) that can largely avoid thermal bridging.

A DER using combined rigid foam and SPF on the exterior walls of a 100-year-old home demonstrates the SPF technique previously described but with furring strips held from the block wall with metal brackets (Yost 2009). This allowed 3.5 in. of closed cell SPF to be applied to the original block while minimizing thermal bridging. The foam will not fully expand to the front edge of the furring strip, leaving an air gap and drainage plane behind the new cladding.

Foam-Tech (a division of Building Envelope Solutions) is a company in Vermont that focuses its business primarily on commercial and industrial applications (Building Envelope Solutions 2012). The company's website, though, provides case study information relevant to anyone contemplating spray foam technology as an interior insulation and air sealing strategy to prevent ice dams. To understand what caused the problem and where to focus solutions, the company begins all of its remediation with on-site testing and data collection. It is also interesting to note that the company has a formal plan to provide post-work temperature monitoring, infrared testing, and visual inspection to determine if applied strategies were functioning or what solutions are necessary to fix the attempted mitigation.

2.5 Alternate Processes and Materials for Exterior Overcoat

The ETMMS solution recommends using an air barrier membrane between the foam and roof sheathing. A liquid applied membrane could be a possible alternative to the typical peel and stick membrane. In the Midwest, liquid applied membrane costs are roughly \$0.60/ft^2 for product and installation (Schirber 2012). This compares to peel and stick that is roughly \$3.26/ft^2 for product and installation (based on product at \$125 for a 99-ft^2 roll and labor at \$2/ft^2).

An alternate material to rigid foam exterior insulation would be the use of mineral wool board. In 2009, the New York City area prices were around \$0.25 ft^2 for 1-in.-thick boards (approximately R-4.2 per inch) up to \$1.00 ft^2 for 2-in.-thick, foil-faced boards (Ehrlich 2009).

Some rigid foam board manufacturers make their products with built-in furring strips that could be customized to extend beyond the face of the foam board. This would result in a built-in ventilation area between foam board and roof sheathing (DF 2012).

3 Overcoat Impact Study

The MLS (2012) and the U.S. Census Bureau (2010) were used to estimate the number of 1½-story homes that exist in Minnesota. From this information, a rough estimate was created to define the number of homes that could be potentially improved with an overcoat approach.

The Minneapolis MLS website represents all listings in the state of Minnesota registered by state-licensed real estate brokers. Although the MLS does not include properties being sold directly by owners, it is the number one source in the state for locating homes for sale. The site was queried to get some preliminary data about the proportion of 1½-story homes, relative to other house types, in Minnesota (MLS 2012). On February 27, 2012, there were 15,463 single-family homes for sale. Of those, 2,178 (14.1%) were listed as 1½-story houses.

The Census Bureau provides statistical data on housing by type (e.g., single-family detached and single-family attached among others (U.S. Census Bureau 2010). A query of this website found there are 1,571,436 single-family detached housing units in Minnesota. As a crude estimate of the number of 1½-story houses that could potentially benefit from an exterior roof insulation overcoat strategy, 14.1% of 1,571,436 results in a figure of 221,572 homes in the state of Minnesota alone.

This study was limited to the Minneapolis MLS. This number, though, is expected to be representative of other cold-climate cities in other states, bringing the total number of 1½-story homes that could benefit from an overcoat approach into the millions.

4 Contractor Interviews

The Northern*STAR* team conducted interviews with six contractors from two cold-climate regions in the United States, the Midwest and the Northeast. The contractors have experience with installing exterior roof insulation and a known or stated focus on roof retrofits, particularly in response to ice dam problems. The goal was to gain field insight into problems and solutions for scalability related to material availability and cost, contractor training, and construction technique. Each contractor was provided with a script of questions from which they could prepare for the telephone interview (see Appendix A for the actual contractor interview template). A follow-up phone interview was employed to ask further questions. Key interview questions covered the following:

- Scope of company services including range of energy and ice dam solutions offered
- Cost, ease of construction, durability, and hygrothermal performance of energy and ice dam solutions offered
- Pre- and post-assessment process
- Overall design issues and approach to critical details
- Material and labor costs
- Marketing strategies for energy efficiency and ice dam services.

The contractors were also asked for their opinions on what single change could significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems in existing homes.

Table 1 gives an overview of each company, its location, and its experience with ice dam retrofits.

Table 1. Contractor Overview

Contractor	Garland Mill Timberframes	Synergy Construction	Byggmeister	Mindel and Morse Builders	Cocoon	Panelworks Plus
Location	New Hampshire	Massachusetts	Massachusetts	Vermont	Minnesota	Minnesota
Years in Energy Retrofit	25	3	20	30	4	10
# Ice Dam Retrofits in Past 5 Years	4–5 as part of whole house overcoat	2, roof only	20–25	2–3	112	5
Type of Case Study Provided	NA	NA	Interior Retrofit	Interior Retrofit	ETMMS	SIP Roof Retrofit Panel
Cost per Square Foot for Case Study Provided	NA	NA	$16.00 for materials and labor	$21.74 for materials and labor	$12.00 for materials and labor	$5.60 for 4-in. panel and labor

Table 2 summarizes the types of strategies employed for addressing ice dams.

Table 2. Types of Ice Dam Mitigation Strategies Employed by Contractors

Exterior Roofing Strategy	Number of Companies That Use Each Strategy
Ice Belt	2
Metal Roof	1
Interior Air Sealing and Insulation	4
SIP and Nailbase SIP	2
Exterior Strapping and Spray Foam Insulation	1
Exterior Strapping and Rigid Foam Insulation	1
ETMMS-Like Approach	4
Roof Geometry Modification	1

4.1 General Comments From Contractor Interviews

4.1.1 Solution Generation Phase

Before starting a construction project, all the participating contractors engage in some type of process that helps them determine which solution to offer for ice dam or energy efficiency improvement, or both. All the contractors cited building details, client budget, and other planned work as key determinants. Additional information may come from the use of a pre-assessment form, photographs, and visual inspection. A few contractors have even been involved in some form of preconstruction testing. Only two builders consistently use a blower door test to uncover air bypass routes, but a few builders received this information through the project architect or building scientist. These contractors have come to recognize the value of the information as a way to create more effective ice dam strategies and stated their intention to hire this test on their next projects.

Those builders that engage in preconstruction testing on a regular basis believe that the information uncovered during this critical phase helps educate clients on the real causes of ice dams and energy loss. This exchange of information seems to be critical to moving potential customers from band-aid approaches to true solution sets.

In regards to actual construction concerns when using an overcoat approach, the participating contractors that have experience cite deeper and taller roofs as requiring more time and greater cost. This may deter other contractors from seeking this solution for their clients.

4.1.2 Construction Phase

Of the concerns expressed by the contractors using an overcoat approach, how and when to vent an assembly appears to be the most confusing. The remodelers are uncertain about when the assembly should be vented and if the roof assembly or the cladding should be vented. Although the literature review sheds some light on these issues, the research is not always in agreement and the lack of conclusive understanding in the industry is evident in the contractors' responses.

4.1.3 Post-construction Phase

It is interesting to note that there is a general understanding among the contractors interviewed about the importance of post-construction review of a project. Two of the contractors always use blower door performance testing; the majority of the remaining contractors have been involved in projects where post-construction testing was completed. The important nature of post-construction testing has led two contractors to purchase their own blower door equipment.

There was, however, a shared understanding of the impact of tightening a home on occupant ventilation. As a result, five of the six contractors have recommended the use of a heat recovery ventilator (HRV) or other mechanical ventilation in some or all of their projects. What is not widely understood is the "house as a system" approach. Occupant ventilation was a concern for most contractors, but only two were concerned about moisture and carbon monoxide issues that can result from tightening a home. These two contractors calculate heating needs as a result of the energy improvements and recommend heating replacement as part of an energy upgrade. One consistently tests for post-construction radon levels and combustion safety. The other frequently uses temperature and moisture monitoring before and after retrofits.

4.1.4 Sales and Marketing

All the contractors interviewed have experienced competition from other contractors that sell band-aid approaches to ice dam mitigation. A few contractors have responded to the competition by providing such approaches to keep a client. Yet the contractors with a more sophisticated approach to performance testing seemed to have an equally sophisticated approach to marketing and greater success with offering more advanced solutions. They often used collateral pieces or websites, or rely on their reputation for ice dam solutions. These contractors also cited building science experts when talking with clients about ice dam formation and solutions. Two of the cited experts include Lstiburek (2008) and Rose (2005, p. 113).

One of the final contractor interview questions asked contractors what they believed to be the single most important or influential change that would significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems. There was no consensus in response. Half the contractors, though, believe that using metrics, especially information from diagnostic testing, is important to help clients understand how ice dams are formed and what that means for long-term solutions. Deferred maintenance, owner desire to stay in the homes, education, and carbon tax were also cited as important considerations for improving homeowner buy-in.

4.2 Noteworthy Comments From Contractor Interviews

4.2.1 Garland Mill Timberframes

Ben Southworth, president of Garland Mill, stated that they work with both BSC and Marc Rosenbaum, an energy engineer/building scientist, on DER projects to ensure that their building assemblies are high performance. The company, however, prefers to work on homes with flat ceilings and vented roofs because of the ease, cost, and opportunities for long-term success. Garland Mill has developed a system in which their experts follow behind their air sealing contractor with a can of spray paint to highlight areas where foam is installed incorrectly. The air sealing contractor has to correct the spray-painted spots.

Garland Mill has a unique way to address super-tall fascia when topside new roof framing is used. The existing soffit assembly is removed, eave walls are plumb cut flush, and then a traditionally sized eave soffit is built. This essentially increases the total height/appearance of the eave wall. The drawback to this approach is that it changes the aesthetic of the height of the wall over eave wall windows.

This company tends to avoid SIPs because of problems related to product quality and air sealing. The most influential factors affecting proposed solutions are budget and exterior architectural details.

4.2.2 Synergy

Synergy has participated in many whole-house DERs using the ETMMS approach through the National Grid Program. Synergy's success with the process has led them to aggressively promote the ETMMS solution. The decline in National Grid whole-house funding, though, has led Synergy to promote smaller projects, such as roofs, using the ETMMS approach. Although performance testing was managed by outside consultants on whole-house overcoat projects, Synergy representatives sees their company moving into the use of performance testing to guide their solutions development process.

4.2.3 Byggmeister

Byggmeister's experience with nailbase SIPs cites excess waste with complex roofs as a reason to discontinue using the approach. The optimal exterior retrofit approach includes rigid insulation with access to the roof framing cavities to increase insulation opportunities and to prevent excess thickness of exterior foam from complicating the installation.

Paul Eldrenkamp, president of Byggmeister, cites building details and client budget as key factors that drive solutions development. Age or newness of the roof cladding may not prevent a homeowner from pursuing an exterior insulation solution, especially if it promises to be the best solution.

Figure 18 illustrates a project in which the historical relevance of the home and complexity of the roof indicated that exterior overcoat would not be the optimal solution. Instead, the existing roof decking was removed and rafter cavities were sealed and insulated with medium density spray foam (R-5). New roof sheathing was installed and the new roof was left unvented.

Figure 18. Exposing rafter cavities to prepare for spray foam insulation

(Courtesy of Byggmeister)

The estimated cost for this type of project was $30,000 or $16/ft^2$.

Byggmeister often uses an OmniSense monitoring system (www.omnisense.com) to monitor before, but most often and most importantly, after the retrofit. The company uses a 12-sensor force measuring sensor (FMS; about $800) and its wireless Internet access ($20/month) to gather relative humidity, temperature, and moisture content from within assemblies. The preconstruction testing helps drive solutions that are offered to homeowners in a comprehensive report.

Byggmeister always tests in and out for radon, but they have never had a project where their work moved the home from below to above the EPA action level, 4 pc/L.

4.2.4 Mindel and Morse Builders

Mindel and Morse Builders has been involved with several projects using nailbase SIPs. Complexity of the projects ranged from simple two-plane roofs to six total dormers. If dormers were present, they were wrapped with exterior rigid foam or rebuilt entirely of SIPs. Adding dormers made of SIPS during a roof retrofit was deemed easy. SIPS were seen as a tighter and less expensive solution to exterior retrofit.

The company reported that exterior approaches are often driven by homeowner desire to maintain an interior aesthetic.

Figures 19, 20, and 21 show an ice dam mitigation project constructed by Mindel and Morse Builders that did not use exterior insulation approach because the homeowner was concerned about the aesthetics of the thickness of the foam. It did, however, include six dormers that were wrapped with exterior rigid foam. The main roof rafter cavity was filled with 7-in. of foil-faced foam rough cut in layers to fill the spaces. This insulation system can be constructed by company crews instead of hiring spray foam contractors. Foam edges were sealed from the exterior using spray foam. The standing seam metal roof cladding was vented.

Figure 19. Foil-faced foam between rafter framing

(Courtesy of Mindel and Morse Builders)

Figure 20. Dormers wrapped in foam

(Courtesy of Mindel and Morse Builders)

Figure 21. Finished roof

(Courtesy of Mindel and Morse Builders)

The six-dormer project covered 27 squares. The job cost for expenses related to the roof insulation was $58,700, or $21.74/ft^2. The new windows and dormer insulation expenses added another $8,000. The standing seam metal roof expenses totaled $22,600.

4.2.5 Cocoon

Cocoon bases its approach to ice dam solutions on pre-work testing and inspection, the condition of existing roof cladding, the roof complexity, and the client's budget.. The company explores the possibilities as they pertain to achievable solutions and work with the homeowner on crafting a good, better, and best approach while trying to align their decision with the measurable outcomes, financial cost and performance benefits. Their goal is to market "to the pain" but to sell "solutions," not products.

Cocoon also actively engages in post-work performance testing and thermal imaging, ventilation measurement, combustion safety, and radon measurement. The company wraps all this information into a customer job report, with recommendations for additional considerations for improved home performance and/or remaining issues. The post-work report to the customer almost always includes HVAC recommendations or considerations.

Steve Schirber, president of Cocoon, indicated that an interior air sealing and insulation approach can be quite challenging. Although attending to the details necessary for long-term durability can be challenging, it can be done in a relatively short period of time and is much less expensive than ETMMS. Interior air sealing is often low in cost and the spray foam is easy to install, but the lack of data on hygrothermal performance of this approach is the reason Cocoon prefers exterior insulation whenever possible for mitigating ice dams. The ETMMS is the more expensive option but it offers the most durable and best hygrothermal solution for ice dams. Because it involves exterior access to eaves and even sometimes top of eave walls, it is a much more invasive process, although it has little impact on day-to-day activities of the occupants. Figure 22 illustrates the process of removing the soffit for access to the eave wall and accommodation of the added thickness of the exterior insulation.

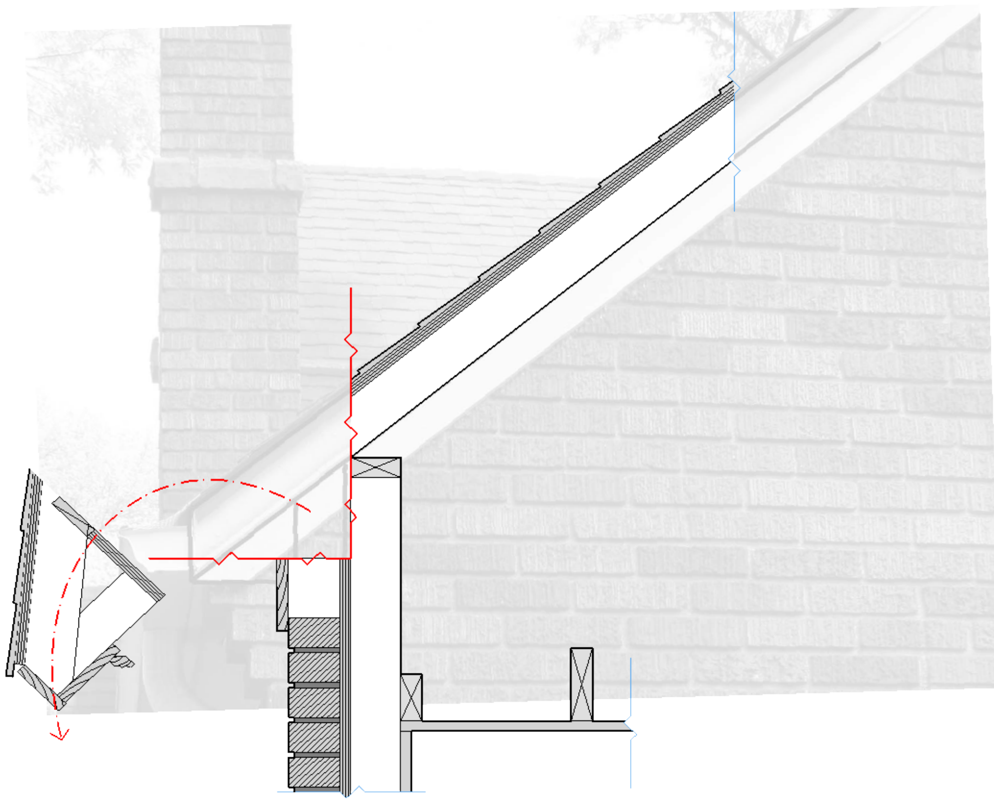


Figure 22. Removing the soffit for an ETMMS approach illustrated by superimposing a drawing of the process over a photograph of the home

(Courtesy of Cocoon)

The open eave allows spray foam insulation to be added at the eave wall to align wall insulation with the exterior insulation plane. Figure 23 illustrates the rigid board insulation over the new air/vapor barrier on the roof sheathing, the new soffit, and the framing lumber placed over the foam to ventilate the roof and support the new roof decking.

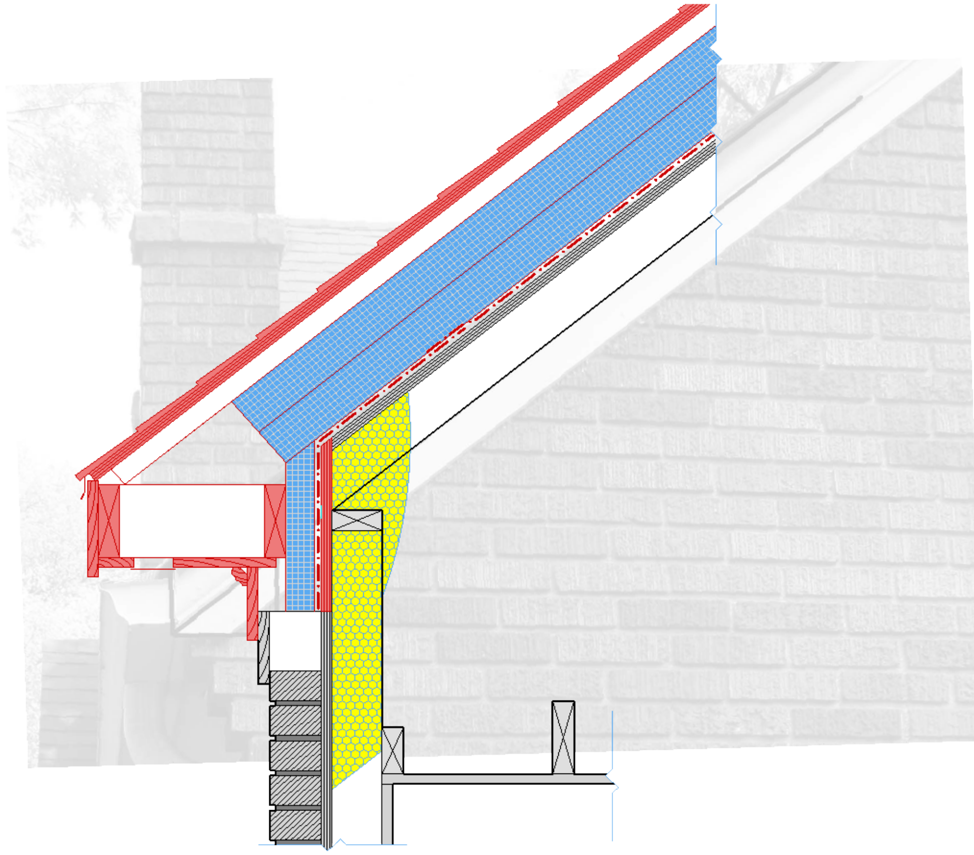


Figure 23. Insulation, air barrier alignment, and soffit construction illustrated by superimposing a drawing of the process over a photograph of the home

(Courtesy of Cocoon)

Figure 24 demonstrates the first protective strategy in an overcoat approach with the use of an air/vapor barrier over the entire roof surface.

Figure 24. Installing the air/vapor barrier over existing roof decking

(Courtesy of Cocoon)

Figure 25 illustrates the transition at the eave wall where the new rigid insulation meets the new vented soffit.

Figure 25. Transition where new insulation meets eave wall and new soffit

(Courtesy of Cocoon)

Figure 26 illustrates the method Cocoon uses to ventilate the roof decking to enable continuous ventilation at the valley.

Figure 26. Ventilation of ETMMS

(Courtesy of Cocoon)

Cocoon representatives believe that there are several circumstances under which homeowners are more likely to consider an ETMMs approach. These include deferred maintenance such as roofing, siding, and windows already in need of repair/replacement; the desire of the homeowner to stay in the house long term; and the homeowner's ability to understand the complexity of building performance and the risk of not completing the project correctly.

4.2.6 Panelworks Plus

At Panelworks Plus, the builders believe that the increased ice dam occurrence during the winter of 2010 is driving the surge in requests for roof retrofits. The lack of snow during the winter of 2011, however, is preventing opportunities to examine the effect of ice dam mitigation efforts from 2010.

A recent project using 4-in. retrofit panels (R-16) that was considered medium in complexity incurred costs of just over $3.00/ft^2 for materials and $2.60/ft^2 for installation. Figure 27 shows the beginning stages of the retrofit application with several panels in place.

Figure 27. SIP retrofit panel installation

(Courtesy of Panelworks Plus)

Thicker R-value SIP retrofit panels make the installation more complex. The presence and number of valleys have more of an impact on the complexity of the installation than any other roof feature. Other roof features that heighten complexity include steep pitches and dormers. Figure 28 highlights the more complex process of detailing dormers.

Figure 28. SIP retrofit panel installation over dormer

(Courtesy of Panelworks Plus)

The company addresses the increased fascia height of exterior SIP installation with a double fascia. Or, if the depth of panels precludes the double fascia, the existing soffit will be plumb-cut to the eave wall and a new soffit will be built, essentially making the eave walls one or more courses of wall cladding "taller." Figure 29 demonstrates the double fascia combined with standing seam metal roof cladding.

Figure 29. SIP retrofit panel installation with double fascia

(Courtesy of Panelworks Plus)

Curt Stendel, president of Panelworks Plus, indicated that increasing panel thickness will add around \$0.45 to \$0.50/ft^2 for each additional 2 in. of foam thickness. Labor costs are driven by the complexity and the size of the roof with cost estimates ranging from \$2.00 to \$3.00/ft^2.

A second project installed in 2010 using 4-in. retrofit panels is realizing a 15% savings on natural gas for heating over the previous year.

The SIP retrofit panel method used by Panelworks Plus does not use an ice and water membrane over the existing roof decking. Panels are carefully sealed to each other to prevent air leakage, but no perimeter air sealing of the panels to the existing structure is undertaken.

5 Conclusions and Further Work

This exploratory study found that the majority of information on exterior overcoat strategies for DERs and ice dam prevention in existing homes has focused on the use of the ETMMS technique. In this technique, continuous air, moisture, and thermal barrier systems are applied on the outside of the building envelope for improved overall performance. The ETMMS research data has been mainly documented for whole-house, DERs, which has left a void in information for roof-only applications.

Some SIP manufacturers and installers are also promoting a SIP retrofit panel as a solution to ice dams. Installation techniques vary and do not always include the use of continuous air and moisture barrier systems. The SIP retrofit panel system, however (sheathing and insulation) is a component of an ETMMS approach and could easily be promoted as part of an ETMMS protocol if installed accordingly.

5.1 Energy Efficiency and Ice Dam Prevention/Durability

A fair amount of information found during the literature review discussed the energy efficiency opportunities, or R-value capabilities, of exterior whole-house overcoat approaches. Roof insulation values of R-60 and above were possible when new roof cavity and overcoat insulation could be applied together. Case studies reviewed by the Northern*STAR* team indicate that exterior insulation systems can produce significant reductions in energy use. But there is little information on expected energy performance when new and old systems and materials are combined for roof-only applications.

Very little research could be found that documents roof, wall, and/or foundation wall durability and post-construction hygrothermal performance. It is not known whether the subjects of the case studies are performing as predicted in preventing ice dams or interior moisture accumulation. The contractor interviews, though, indicated that there is an understanding among high performance contractors in the industry that exterior overcoat strategies have the best potential to address energy efficiency, durability, and ice dam prevention in existing homes. Overcoat would be their preferred method of roof insulation in most situations.

Only one study, George, M. (2012), looked at the impact of adding overcoat measures to existing insulation and vapor barriers in wall systems. Further research would be needed to make conclusions about the performance impact of new overcoat measures combined with existing roof insulation type and R-value. There are also other issues besides the installed R-value of the existing insulation including insulation condition, contamination, presences of vapor retarders, and venting in the existing assembly.

The BSC studies (Straube and Grin 2010, Lstiburek 2011, Pettit 2009, Lstiburek 2008) present optimal strategies for achieving DERs where insulation levels between roof rafters and the exterior insulation levels are optimized for snow load. Not all exterior roof retrofit projects will be able to improve interior insulation or add enough exterior insulation to meet the optimal levels described by BSC. Further research will be needed to study the performance impact of varying the levels of new exterior insulation in the presence of existing rafter insulation.

Additional research on roof ventilation for overcoat practices would help clarify when roof ventilation should be applied. Although some research (Lstiburek 2010) suggests that roof ventilation is not needed when R-values meet or exceed R-60, other research (Lstiburek 2008) suggests that it is still necessary in areas of high snow loads and for houses with large roof overhangs and dark claddings. It is not known if there are any existing conditions such as vapor barriers or certain types of insulation that would also preclude the necessity for a vented roof.

5.2 Indoor Environmental Quality

No information was found in the literature review that linked any of the products or systems for exterior overcoat roof insulation to indoor air quality issues, except for research that linked a tighter home with the need to address combustion safety (Lstiburek 2008). There are no data measuring how many contractors that do energy improvements address health and safety, but the lack of consistency in post-construction performance testing, as noted in the contractor interviews, suggest that contractors should be educated about combustion safety.

5.3 Constructability

No studies were found that addressed issues related to specific roof typologies. Nothing could be located in the literature that indicated one roof typology was favored over another or that a specific roof typology could not be addressed through an overcoat approach. The literature review, in fact, indicated that complex roof structures—even those of 1½-story homes with varying typology and obstacles—are capable of receiving exterior insulation if planned and designed well.

BSC (2009) has created numerous cross-section details to furnish the information that design professionals and contractors will need for successful installation of rigid foam overcoat strategies. These details, though, are focused on whole-house integration where the new roof insulation and membrane are tied to the new wall insulation and membrane and all existing insulation is removed. No research could be found that addresses details for aligning new insulation and air/water barriers in the roof with existing insulation and air/water barriers in the walls.

The BSC research and contractor interviews indicate the need for training and construction oversight to ensure that insulation and air barriers are aligned correctly.

5.4 Affordability

The cost information that was found for whole-house overcoat projects was inclusive of additional remodeling strategies needed to bring a house up to code, to repair damaged structural elements, and to add energy efficiency strategies such as new windows or mechanical systems. The cost for the overcoat components and labor were not isolated. As a result, the Northern*STAR* team could form no conclusions about cost for overcoat measures from the literature.

The contractor interviews found a wide range of costs for ice dam mitigation strategies. The approach applied by each contractor varied, making direct cost comparisons difficult. The contractor interviews, however, did offer some insight into costs. This information indicated that ice dam mitigation in 1½-story homes via an interior approach is not always less expensive than exterior approaches. Increased cost in either approach is driven by the complexity of the roof and the need to maintain architectural or historical features.

The overall consensus from the contractor interviews, however, indicates that budget is a key consideration but does not always drive the decision-making process. Changes to architectural and historical features are often determinants for which solution is most appropriate. Home improvements such as new windows, wall cladding, and roofing, or the addition of large dormers in a livable attic provide opportunities for energy retrofits and ice dam mitigations that favor exterior approaches over interior methods.

In terms of cost, some materials not traditionally used for roofing—such as liquid applied membrane and mineral wool insulation— could lower the overall cost for an overcoat approach. Because these materials are not being used for roofing, constructability and durability would have to be researched before the materials could be recommended as replacements for products currently used in the marketplace.

5.5 Assessment Strategies

Some of the contractors interviewed use a pre-assessment process to determine which strategy is best for mitigating ice dams and improving energy efficiency. Those same contractors often begin their assessment with an energy audit using a blower door test and infrared camera scan to determine where air is leaking. These same contractors often include a post-construction blower door test and infrared camera scan to determine that the air sealing measures have been installed correctly. Only one contractor addressed combustion safety and tested for carbon monoxide post-construction.

Only one report in the literature review (George, M. 2012) addressed issues that might occur with preexisting vapor barriers in walls. Because newer 1½-story homes constructed with vapor barriers may experience ice dams, understanding issues related to the presence of these vapor barriers is critical. If further research determines that a home with a vapor barrier requires special consideration for exterior overcoat applications, this would be a good pre-assessment question for a contractor to ask a homeowner.

5.6 Overall Conclusions and Further Work

The BA website addresses best practice strategies for the roof component of new construction and references interior insulation and air ceiling for flat ceilings of existing homes.[2] The website, however, lacks comprehensive information on roof insulation techniques for existing homes in cold-climate regions with complicated roof structures. Results from this research can help direct future BA research activities in efforts to create information for professionals, homeowners, and insurance companies to make decisions about more robust strategies for ice dam prevention.

Construction details that would help a designer or contractor understand how to align new and existing air barriers and insulation when employing an overcoat approach on an existing home are an important component missing from the literature. It is also unknown how beneficial an overcoat approach is for mitigating ice dams and improving energy efficiency because ETMMS studies have not been isolated to roof-only projects. Further research would be necessary to truly understand the costs associated with a roof overcoat approach and whether or not alternate materials and processes can be put in place to lower costs.

[2] For more information, see Building America http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/26450.pdf

The lack of pre- and post-construction blower door depressurization, infrared thermal imaging, and combustion safety testing also gives BA an opportunity to evaluate methods that improve performance outcome and reduce contractor risk by addressing occupant safety.

Because most of the existing research and supporting strategies for exterior overcoat are based on the ETMMS whole-house approach, this is the most logical process to study. Monitoring actual ETMMS field installations of multiple roof projects would yield more robust cost, constructability, durability, and performance data that could lead to scalability opportunities for the millions of 1½-story homes in snowy regions of the country.

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Appendix A. Project Overcoat Contractor Interview Template

Problem Statement:
Ice dams are a huge problem in existing homes in cold, snowy climates. We are evaluating just how retrofit contractors and their clients select a solution, particularly for story-and-a-half homes. We are especially interested in the conditions, methods, cost, and marketing of exterior insulation roof retrofits in the context of effectively solving ice dam problems.

<u>Background Info:</u>

1. Interviewee Name:

2. Interviewee Title:

3. Company Name:

4. Location of Business:

5. Complete scope or range of company services: Energy retrofits to solve comfort, utility bill and ice dam problems

6. Years in energy retrofit business:

7. Number of "ice dam" retrofits completed in last 5 years:

<u>Questions:</u>

When a potential client comes to you to with an ice dam problem:

1. What information do you need before proposing solutions to the client?
    a. Assessment/inspection form
    b. Pre-work testing (blower door, infra-red imaging, etc.)
    c. Client financial "aptitude"

2. What is the full range of ice dam solutions your company provides?

3. How would you rate each of the above based on:
    a. Relative cost
    b. Ease of construction/feasibility
    c. Durability
    d. Hygrothermal performance (combined energy and moisture management performance)

4. What resources do you use to explain the phenomenon of ice dams to your clients?

5. What are the factors that drive which solutions you propose?
    a. Building details (roof complexity, extent of the ice dam problem, age of roof cladding, roof pitch)
    b. Client budget

   c. Sequenced or planned previous or future work

6. Check out the 5 common roof types on the last page of this questionnaire:
   a. Is there one or two that you most commonly deal with in ice dam work?
   b. Is there any relationship between roof type and which solution you propose?

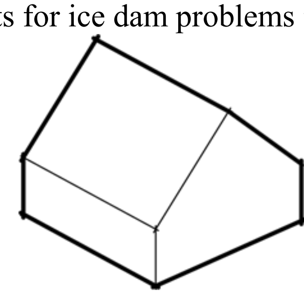
7. What sort of post-job evaluation or results do you gather?

8. How often are mechanical system changes/retrofits associated with your building envelope work (adding spot exhaust ventilation, whole-house ventilation, or radon mitigation)?

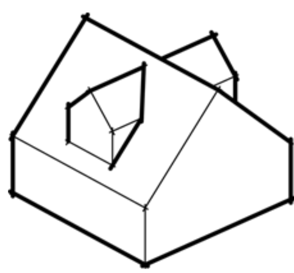
9. How do you specifically market your ice dam/roof retrofit solutions, especially in the context of what you consider to be the competition for effectively solving ice dam problems (e.g., heat tape, roof raking, installing a standing seam metal roof—complete or just the eaves)?

10. Can you provide documentation for one or more of your recent ice dam-driven roof energy retrofits:
    a. Inspection/assessment
    b. Before/after images (digital/IR [infrared])
    c. Construction details
    d. Pre-/post-testing results
    e. Cost details (labor/materials/profit; bid/cost-plus contract, etc.)

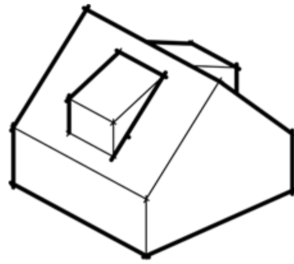
11. What do you think is the single most important or influential change that would significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems in existing homes?



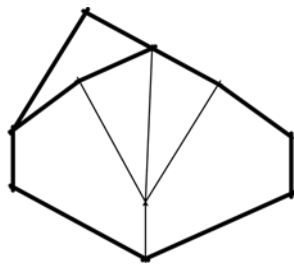
2 plane, 2 gable



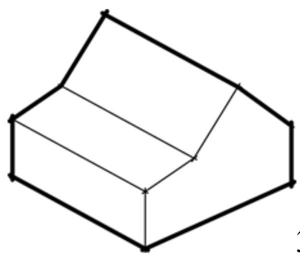
2 plane, 2 gable with gable dormers



2 plane, 2 gable with shed dormers



4 plane, 3 gable



3 plane, 2 gable

Appendix B. Project Overcoat Contractor Interview—Garland Mill Timberframes

Problem Statement:
Ice dams are a huge problem in existing homes in cold, snowy climates. We are evaluating just how retrofit contractors and their clients select a solution, particularly for story-and-a-half homes. We are especially interested in the conditions, methods, cost, and marketing of exterior insulation roof retrofits in the context of effectively solving ice dam problems.

Background Info:
1. Interviewee Name: Ben Southworth

2. Interviewee Title: President

3. Company Name: Garland Mill Timberframes (www.garlandmill.com/)

4. Location of Business: Lancaster, NH

5. Complete scope or range of company services—mainly new construction and some DERs, including company purchase of foreclosed homes for major renovation and then rental

6. Years in energy retrofit business: DERs for 5 years, energy efficient new construction and retrofit for 25 years

7. Number of "ice dam" retrofits completed in last 5 years: 4—5 DERs in which ice dams were a part of the puzzle

Questions:
When a potential client comes to you to with an ice dam problem:
1. What information do you need before proposing solutions to the client?
   a. Assessment/inspection form - no
   b. Pre-work testing (blower door, infra-red imaging, etc.)—blower door and fogging
   c. Client financial "aptitude"—yes, always

2. What is the full range of ice dam solutions your company provides?
   a. Interior air sealing and insulation
   b. Exterior SIP and air sealing
   c. Exterior strapping/framing with spray foam or more typically, cellulose cavity fill
   d. Exterior rigid insulation (almost always using salvaged rigid insulation purchased from Conigliaro Industries)

3. How would you rate each of the above based on:
   a. Relative cost
   b. Ease of construction/feasibility
   c. Durability

d. Hygrothermal performance (combined energy and moisture management performance)

Southworth follows the building science recommendations created by Building Science Corporation and Marc Rosenbaum of South Mountain Company. Of the techniques listed in #2 above, the least expensive approach tends to be c, air seal with foam and then topside new roof framing cavity filled with cellulose.

NOTE: an innovative way that Garland Mill deals with the super-tall fascia when topside new roof framing is used: plumb cut flush the eave walls (remove existing soffit assembly) and then rebuild a traditionally sized eave soffit, essentially increasing the total height/appearance of the eave wall. This does change the aesthetic of the height-of-wall over eave wall windows, though.

Southworth tends away from SIP products because of ongoing concerns about PBTs [polybutylene terephthalate] in the fire retardants and high GWP [global warming potential] of the different foams used in SIPS. Will limit use of these foams until there is more information is available to make better decisions on use.

4. What resources do you use to explain the phenomenon of ice dams to your clients? Uses Joe Lstiburek's newsletter on ice dams from 2011 (www.buildingscience.com/documents/insights/bsi-046-dam-ice-dam/?searchterm=ice%20dams).

5. What are the factors that drive which solutions you propose?

a. Building details (roof complexity, extent of the ice dam problem, age of roof cladding, roof pitch)

b. Client budget

c. Sequenced or planned previous or future work

The most influential factors affecting proposed solutions are budget AND exterior architectural details (namely eave and gable overhangs and whether or not the overhangs remain or will be removed and rebuilt).

Also, Garland Mills has a strong preference for working on homes with flat ceilings/vented, unconditioned attics because it is so much easier and cheaper to air seal and insulate a flat ceiling rather than a cathedral or cathedralized attic. Typical home they can air seal and insulate (2 feet of cellulose) an attic for $3,000.

6. Check out the 5 common roof types on the last page of this questionnaire:

a. Is there one or two that you most commonly deal with in ice dam work? Two-plane and doghouse dormers

b. Is there any relationship between roof type and which solution you propose? See response above #5.

7. What sort of post-job evaluation or results do you gather? Blower door with targeted result.

An interesting quality control item that Garland Mill conducts is following behind their air sealing contractor with a can of spray paint, highlighting areas where the foam is deficient, rolled over on itself, or misapplied. The insulation/air sealing contractor has to go back and attend to all the spray painted spots, essentially covering the paint with their corrected work.

8. How often are mechanical system changes/retrofits associated with your building envelope work (adding spot exhaust ventilation, whole-house ventilation, or radon mitigation)? Changes in heating unit (typically boiler) almost never. Addition of whole house mechanical ventilation (an HRV) always.

9. How do you specifically market your ice dam/roof retrofit solutions, especially in the context of what you consider to be the competition for effectively solving ice dam problems (e.g. heat tape, roof raking, installing a standing seam metal roof—complete or just the eaves)? N/A—Garland Mill does virtually NO ice dam-driven energy retrofits.

10. Can you provide documentation for one or more of your recent ice dam-driven roof energy retrofits:
    a. Inspection/assessment
    b. Before/after images (digital/IR)
    c. Construction details
    d. Pre-/post-testing results
    e. Cost details (labor/materials/profit; bid/cost-plus contract, etc.)

       Ben is considering providing info on one of their projects, but cannot by the January 31 deadline.

11. What do you think is the single most important or influential change that would significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems in existing homes?

    Metrics—increasing his company's depth and capabilities in building performance measurements.

Appendix C. Project Overcoat Contractor Interview—Synergy Construction

Problem Statement:
Ice dams are a huge problem in existing homes in cold, snowy climates. We are evaluating just how retrofit contractors and their clients select a solution, particularly for story-and-a-half homes. We are especially interested in the conditions, methods, cost, and marketing of exterior insulation roof retrofits in the context of effectively solving ice dam problems.

Background Info:

1. Interviewee Name—Alex Cheimets

2. Interviewee Title—VP, Sales and Marketing

3. Company Name—Synergy Construction (http://synergy-green-builders.com/)

4. Location of Business—Leominster, MA

5. Complete scope or range of company services: high performance new homes and deep energy retrofits

6. Years in energy retrofit business—real push to high performance in last 3 years

7. Number of "ice dam" retrofits completed in last 5 years—plenty of bids but only two roof-only retrofits

Questions:
When a potential client comes to you to with an ice dam problem:

1. What information do you need before proposing solutions to the client?
   a. Assessment/inspection form - no
   b. Pre-work testing (blower door, infra-red imaging, etc.) - no
   c. Client financial "aptitude"—yes

2. What is the full range of ice dam solutions your company provides? ETMMS primarily; Synergy has done a lot of DERs within the National Grid Program (https://www.powerofaction.com/der/) but that money is really drying up right about now, so more of the work Synergy is bidding is NOT whole-house deep energy retrofits but more "piece" work like roof retrofits.

   NOTE: one recent project, a very complicated slate roof, forced Synergy to do an interior roof retrofit: detailed air sealing with cellulose fill. This is not the preferred approach for Synergy because only the topside rigid insulation gives the thermal bridging solution and superior air seal.

NOTE: Synergy has done a number of retrofits from inside the attic. Synergy believes that the best retrofit is from exterior, but most of their projects, including those with exterior insulation, include an interior attic component.

When the roof is new, or slate, or for economic reasons, Synergy will suggest all the work be interior. Because of NGrid and NStar, though, many of Synergy's projects need exterior insulation to reach utility program R-levels (R-60).

Synergy believes that the mix between exterior and interior will become more balanced.

3. How would you rate each of the above based on:
    a. Relative cost
    b. Ease of construction/feasibility
    c. Durability
    d. Hygrothermal performance (combined energy and moisture management performance)

    The ETMMS solution is all that Synergy does. They feel it is the best solution, but although they have a very aggressive marketing program for this approach, they have lost quite a few bids of late based on cost and the dwindling of the National Grid DER program.

4. What resources do you use to explain the phenomenon of ice dams to your clients? n/a

5. What are the factors that drive which solutions you propose
    a. Building details (roof complexity, extent of the ice dam problem, age of roof cladding, roof pitch)
    b. Client budget
    c. Sequenced or planned previous or future work

    See 2 above: essentially, Synergy works from the exterior unless some condition, like a slate roof that has to stay, precludes this approach.

6. Check out the 5 common roof types on the last page of this questionnaire:
    a. Is there one or two that you most commonly deal with in ice dam work? No, all types.
    b. Is there any relationship between roof type and which solution you propose? No, not really, even complicated roofs can be handled effectively and efficiently with ETMMS—see http://synergy-green-builders.com/concord-partial-retrofit-new-roof/ .

7. What sort of post-job evaluation or results do you gather? On the National Grid projects, Building Science Corp is the consultant and always does pre- and post blower door testing. Never thermal imaging. On non-National Grid projects, no testing currently, and certainly not for roof-only projects (Cheimets was surprised to hear, but then understood, that roof-only projects can give air tightening results worth capturing quantitatively). But

with the apparent ending of the National Grid Program, Cheimets stated that gaining performance measurement capability was really important.

8. How often are mechanical system changes/retrofits associated with your building envelope work (adding spot exhaust ventilation, whole-house ventilation, or radon mitigation)? With DERs, required, but not for roof-only work.

9. How do you specifically market your ice dam/roof retrofit solutions, especially in the context of what you consider to be the competition for effectively solving ice dam problems (e.g. heat tape, roof raking, installing a standing seam metal roof—complete or just the eaves)? Free consultation approach to selling high performance solutions: http://synergy-green-builders.com/request-quote/ .

10. Can you provide documentation for one or more of your recent ice dam-driven roof energy retrofits:
    a. Inspection/assessment
    b. Before/after images (digital/IR)
    c. Construction details
    d. Pre-/post-testing results
    e. Cost details (labor/materials/profit; bid/cost-plus contract, etc.)

    Alex would not commit to providing a project, but I am working on him to provide more info on recent ice-dam bids they have won/lost and to provide cost info for the one roof-only project they have on their website: http://synergy-green-builders.com/concord-partial-retrofit-new-roof/ .

11. What do you think is the single most important or influential change that would significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems in existing homes?

    As the marketing guy at Synergy, Alex seemed very interested in connecting performance metrics to their marketing, particularly with the National Grid work fading.

Appendix D. Project Overcoat Contractor Interview—Byggmeister

Problem Statement:
Ice dams are a huge problem in existing homes in cold, snowy climates. We are evaluating just how retrofit contractors and their clients select a solution, particularly for story-and-a-half homes. We are especially interested in the conditions, methods, cost, and marketing of exterior insulation roof retrofits in the context of effectively solving ice dam problems.

Background Info:

1. Interviewee Name: Paul Eldrenkamp
2. Interviewee Title: President
3. Company Name: Byggmeister (www.byggmeister.com/index.shtml)
4. Location of Business: Newton, MA (5600 HDD [heating degree days])
5. Complete scope or range of company services: Exclusively remodeling, high performance retrofits
6. Years in energy retrofit business: 20
7. Number of "ice dam" retrofits completed in last 5 years: 20—25 roof retrofits (does about 30—40 projects per year)

Questions:
When a potential client comes to you to with an ice dam problem:

1. What information do you need before proposing solutions to the client?
    a. Assessment/inspection form—no, visual inspection plus info/photos from client
    b. Pre-work testing (blower door, infra-red imaging, etc.)—sometimes, depends on if the project has "mysteries" or not
    c. Client financial "aptitude"—absolutely, always competing against "band-aid" approaches

2. What is the full range of ice dam solutions your company provides?
    a. Interior air sealing and insulation
    b. Exterior only (rigid insulation or something close to the ETMMS)
    c. Ideally, exterior with access to roof framing cavities

    NOTE: Paul mentioned that the complexity of his roof projects means they never use nailbase panels—just too many cuts and different thicknesses of insulation required so from a cost and waste perspective, always does rigid insulation.

    NOTE: if after all is said and done the customer wants to go with a band-aid approach, Byggmeister won't do it and sends the client somewhere else.

3. How would you rate each of the above based on:
    a. Relative cost
    b. Ease of construction/feasibility
    c. Durability
    d. Hygrothermal performance (combined energy and moisture management performance)

Best solution is (c) from hygrothermal/durability perspective, but also the most expensive. (b) is challenging architecturally and the deeper the exterior insulation approach, the tougher (and more expensive) more-complicated roofs become.

4. What resources do you use to explain the phenomenon of ice dams to your clients?

Generally, just verbal BUT if the client seems to want or need a resource (Paul's company reputation means that they generally defer to his professional judgment quite a bit), the best one is in Bill Rose's book, *Water in Buildings,* Chapter 4, Roofs and Facades, pg. 113, Ice Dams).

5. What are the factors that drive which solutions you propose
    a. Building details (roof complexity, extent of the ice dam problem, age of roof cladding, roof pitch)
    b. Client budget
    c. Sequenced or planned previous or future work

    All of the above, but a and b are paramount and related, often. Paul mentioned that the age or newness of the roof cladding was not quite as important or influential as you might think—sometimes the problem means tearing off a perfectly good roof cladding because the solution requires it.

6. Check out the 5 common roof types on the last page of this questionnaire:
    a. Is there one or two that you most commonly deal with in ice dam work?
    b. Is there any relationship between roof type and which solution you propose?

    Paul proposed that all of his projects would require Figures 6—12; his projects tend to have very complicated roof configurations and architectural details.

    NOTE: the complicated details are existing conditions; Byggmeister strives to simplify roof details as a design policy in their work.

7. What sort of post-job evaluation or results do you gather?
    a. Blower door
    b. IR imaging
    c. Monitoring

    Paul uses an OmniSense system (www.omnisense.com/) as often as he can with clients to monitor before but most often and most importantly after the retrofit. He uses a12-sensor [force measuring sensor] (about $800) and then their wireless internet access ($20/month) to gather RH [relative humidity], temp, and moisture content from within assemblies.

8. How often are mechanical system changes/retrofits associated with your building envelope work (adding spot exhaust ventilation, whole-house ventilation, or radon mitigation)? About 10% of the time. On the low end, Paul will recommend a FanCycler system and on the high end an HRV. Byggmeister always tests in and out for radon, but they have never had a project where their work moved the home from below to above the EPA action level, 4 pc/L.

9. How do you specifically market your ice dam/roof retrofit solutions, especially in the context of what you consider to be the competition for effectively solving ice dam problems (e.g., heat tape, roof raking, installing a standing seam metal roof—complete or just the eaves)? Byggmeister does not target market their roof retrofits; high performance is at the heart of all their marketing/company positioning.

10. Can you provide documentation for one or more of your recent ice dam-driven roof energy retrofits:
    a. Inspection/assessment
    b. Before/after images (digital/IR)
    c. Construction details
    d. Pre-/post-testing results
    e. Cost details (labor/materials/profit; bid/cost-plus contract, etc.)

    Paul will do his best to provide us with one of his projects. The good news is he has been doing performance testing and monitoring on two recent projects. The bad news is that they are roof retrofits from last year, so he does not really have a full winter (this winter) of "after" data. He has promised the *Journal of Light Construction* [JLC] "first dibs" on this roof retrofit and monitoring work but will share with us what he can as long as we don't in any way "scoop" JLC.

11. What do you think is the single most important or influential change that would significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems in existing homes? Carbon tax to drive the economics of truly high performance solutions. Yes, exterior roof retrofits are more expensive, but if the cost of energy reflected all of its true costs, the economics would support the higher performance solutions. Right now, the "best" solutions—exterior roof retrofits—move the cost from about $10k to $60k. That is a tough sell.

Appendix E. Project Overcoat Contractor Interview—Mindel and Morse Builders Problem Statement:

Ice dams are a huge problem in existing homes in cold, snowy climates. We are evaluating just how retrofit contractors and their clients select a solution, particularly for story-and-a-half homes. We are especially interested in the conditions, methods, cost, and marketing of exterior insulation roof retrofits in the context of effectively solving ice dam problems.

Background Info:

1. Interviewee Name: Steve Mindel

2. Interviewee Title: President

3. Company Name: Mindel and Morse Builders

4. Location of Business: Dummerston, VT

5. Complete scope or range of company services—full service renovation and new construction company

6. Years in energy retrofit business—energy efficient construction for 30 years (began using exterior rigid foam on walls in 1981)

7. Number of "ice dam" retrofits completed in last 5 years—2, and 3 including roof retrofit (longer than 5 years ago: 2—3 more)

Questions:

When a potential client comes to you to with an ice dam problem:

1. What information do you need before proposing solutions to the client?
    a. Assessment/inspection form - no
    b. Pre-work testing (blower door, infra-red imaging, etc.)- no (but should—need to gain the capability in-house)
    c. Client financial "aptitude"—not really

2. What is the full range of ice dam solutions your company provides?
    a. Ice belt ("band-aid" approach, admittedly)
    b. Standing seam metal roof ("band-aid" approach, admittedly)
    c. Exterior rigid insulation w/ strapping
    d. Cavity fill and air sealing
    e. Nail base

    Green River project (6 sloped roof doghouse dormers)—dormers wrapped with exterior rigid foam with main roof: cavity foil face, rough cut in layers to fill spaces, edges spray foamed as air seal, blow cellulose, "hot roof" (unvented roof framing cavities) with roof cladding ventilation topside (current project). No exterior rigid foam topside because of overall project cost concerns and impact on exterior aesthetic.

On the following projects, nailbase SIPs were used on the roofs with doghouse dormers either wrapped with exterior rigid foam or dormers rebuilt entirely from SIPs. In each of the three, an exterior approach was driven by client's desire to maintain interior aesthetic of exposed framing and underside of roof board sheathing.

f. Baker Brook project (simple—two planes)

g. Newfane project (one doghouse dormer—wrapped with SIPs)

h. Guilford project (6 doghouse new SIPs)—SIPs on top with blown cellulose in sleeper cavity essentially as a fire stop (has added this detail due to concerns that having a dead air space in the middle of the new roof assembly would allow a fire to stay "hidden" in this space).

i.

Note: The Newfane project with the single dormer is where we filled the sleeper space.

Eave detailing - foamed eave

SIPs were tighter and less expensive (nailbase)

Interesting phenomenon with skylights, particularly on north slope; differential melting around skylight—solution is to rake below skylight

Special Note: adding dormers in a roof retrofit constructed of SIPs is really easy

3. How would you rate each of the above based on:
   a. Relative cost
   b. Ease of construction/feasibility
   c. Durability
   d. Hygrothermal performance (combined energy and moisture management performance)

Solving the heat and air loss problem means taking the whole roof system apart. Any of the external systems work at this point in the process, the cost and "convincing" is all about taking the roof apart, from the outside. So, most expensive solution is the most durable and best hygrothermal performance.

4. What resources do you use to explain the phenomenon of ice dams to your clients?

Verbal explanation—new JLC cover article on ice dams – planning on using that.

5. What are the factors that drive which solutions you propose?
    a. Building details (roof complexity, extent of the ice dam problem, age of roof cladding, roof pitch)—all factors. Valleys and hips and dormers are hard to insulate and vent
    b. Client budget – biggest
    c. Sequenced or planned previous or future work

    Because things are currently pretty slow, Steve's company generally prefers solutions that keep his crews working rather than more fully engaging a subcontractor, like spray foam. Steve's company also favors insulation systems with better environmental profiles (rigid insulation—blowing agent is pentane—low global warming potential; closed-cell spray foam blowing agent is high GWP).

6. Check out the 5 common roof types on the last page of this questionnaire:
    a. Is there one or two that you most commonly deal with in ice dam work? Simple and doghouse
    b. Is there any relationship between roof type and which solution you propose? No, largely driven by other factors (aesthetics)

7. What sort of post-job evaluation or results do you gather? None at this point, but wants to use performance pre- and post-testing.

8. How often are mechanical system changes/retrofits associated with your building envelope work (adding spot exhaust ventilation, whole-house ventilation, or radon mitigation)? Added spot ventilation and radon in some cases, based on need. None with balanced systems; just too hard to add the proper ducting—some 24/7 exhaust.

9. How do you specifically market your ice dam/roof retrofit solutions, especially in the context of what you consider to be the competition for effectively solving ice dam problems (e.g. heat tape, roof raking, installing a standing seam metal roof—complete or just the eaves)?

    Steve's company does not do any real marketing. They have been in business long enough in the Brattleboro area that word-of-mouth and referrals is how they get just about all their work, including any ice dam projects. They are always trying to address the cause, not the symptom but not always successful.

10. Can you provide documentation for one or more of your recent ice dam-driven roof energy retrofits:
    a. Inspection/assessment
    b. Before/after images (digital/IR)
    c. Construction details
    d. Pre-/post-testing results
    e. Cost details (labor/materials/profit; bid/cost-plus contract, etc.)

Possibly, on one project: Green River. We stripped 2 layers of shingles and a layer of plywood, then removed the old roof boards. We removed fiberglass batts and filled the cavities with 7 in. of foil-faced polyiso, foaming gaps throughout. We installed ¾-in. plywood, deck armor paper- breathable, then standing seam roofing with backer rod down the center of the roof panels to create an air space.

i. The job was 27 squares and cost $66,700 ($24.70/ft^2).
ii. (less $8,000 for window replacement)

11. What do you think is the single most important or influential change that would significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems in existing homes?

Diagnostic testing—blower door and infrared

Appendix F. Project Overcoat Contractor Interview—Cocoon

Problem Statement:
Ice dams are a huge problem in existing homes in cold, snowy climates. We are evaluating just how retrofit contractors and their clients select a solution, particularly for story-and-a-half homes. We are especially interested in the conditions, methods, cost, and marketing of exterior insulation roof retrofits in the context of effectively solving ice dam problems.

Background Info:

1. Interviewee Name: Steve Schirber/Tessa Murry

2. Interviewee Title: President/Lead Researcher

3. Company Name: Cocoon

4. Location of Business: Edina, MN

5. Complete scope or range of company services: energy retrofits to solve thermal comfort, utility bill and ice dam problems

6. Years in energy retrofit business: 4

7. Number of "ice dam" retrofits completed in last 5 years: 112

8. Questions:
9. When a potential client comes to you to with an ice dam problem:
10. What information do you need before proposing solutions to the client?
    a. Assessment/inspection form - Yes
    b. Pre-work testing (blower door, infra-red imaging, etc.)—Blower door and IR imaging, combustion safety, ventilation, radon
    c. Client financial "aptitude" - Yes

11. What is the full range of ice dam solutions your company provides?
    a. Basic air sealing
    b. Cavity fill and BIB [blow-in blanket] insulation
    c. Roof ventilation
    d. Roof geometry modification
    e. Interior insulation and air sealing
    f. Exterior insulation and air sealing
    g. Exterior foam and false deck overlay
    h. ETMMS
    i. Ventilation - HVAC system design and install

12. How would you rate each of the above based on:
    a. Relative cost

b. Ease of construction/feasibility
c. Durability
d. Hygrothermal performance (combined energy and moisture management performance)

Basic air sealing	5	5	5	1
Cavity fill and BIB insulation	4	5	3	1
Roof ventilation	3	3	3	2
Roof Geometry modification	2	2	5	2
Interior insulation and air sealing	4	3	4	3
Exterior insulation and air sealing	2	2	4	3
Exterior foam and false deck overlay	2	2	4	4
ETMMS	1	1	5	5

1=worst, 5=best

ETMMS is the more expensive option but it offers the most durable and best hygrothermal solution for ice-damming. Since it involves exterior access to eaves and even sometimes top of eave walls, it is a much more invasive process, although it has little impact on day-to-day goings-on of the occupants.

The interior air sealing and insulation approach is quite challenging for the installers, but it can be done in a relatively short period of time and is much less expensive than ETMMS.

13. What resources do you use to explain the phenomenon of ice dams to your clients?

Cocoon has extensive information resources for the general public and its clients on its website: http://cocoon-solutions.com/about-you/resources-for-you/ . These, of course, include reputable information on ice dams, causes and solutions.

14. What are the factors that drive which solutions you propose
    a. Building details (roof complexity, extent of the ice dam problem, age of roof cladding, roof pitch)
    b. Client budget
    c. Sequenced or planned previous or future work

Cocoon bases its approach on the pre-work testing and inspection, the condition of existing roof cladding, the roof complexity, and the budget of the client. In general, we explore the possibilities as it pertains to achievable solutions. From there we work with the homeowner on crafting a good, better, best approach and try to align their decision with the measurable outcomes, financial cost and performance benefits.

15. Check out the 5 common roof types on the last page of this questionnaire:

d. Is there one or two that you most commonly deal with in ice dam work? All of the above
e. Is there any relationship between roof type and which solution you propose? All approaches apply to all shapes and each have their pros and cons. The decision making process highly depends on what is inside.

16. What sort of post-job evaluation or results do you gather?

Cocoon not only does post-work performance testing and thermal imaging, ventilation measurement, combustion safety and radon measurement, but wraps all this information into a customer job report, with recommendations for additional considerations for improved home performance and/or remaining issues.

17. How often are mechanical system changes/retrofits associated with your building envelope work (adding spot exhaust ventilation, whole-house ventilation, or radon mitigation)? See above—the post-building envelope work to the customer almost always includes HVAC recommendation or considerations.

18. How do you specifically market your ice dam/roof retrofit solutions, especially in the context of what you consider to be the competition for effectively solving ice dam problems (e.g. heat tape, roof raking, installing a standing seam metal roof—complete or just the eaves)?

The Cocoon website is a model of how to present information and high performance solutions in comparison to band-aid superficial approaches that do not really solve the underlying causes of ice dam problems. We market to the "pain" and sell "solutions," not product (i.e. insulation)

19. Can you provide documentation for one or more of your recent ice dam-driven roof energy retrofits:

a. Inspection/assessment
b. Before/after images (digital/IR)
c. Construction details
d. Pre-/post-testing results
e. Cost details (labor/materials/profit; bid/cost-plus contract, etc.)

(was not able to supply photo before completion of report)

20. What do you think is the single most important or influential change that would significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems in existing homes?

Deferred maintenance. By this I mean, items like the roof, siding, windows and mechanical systems are already in need of repair/replacement. This factor is highly leveragable. I would also add the desire of the home owner to stay in the house long term, and their ability to understand the complexity of building performance and the risk of not doing it right.

Appendix G. Project Overcoat Contractor Interview—Panelworks Plus

Problem Statement:
Ice dams are a huge problem in existing homes in cold, snowy climates. We are evaluating just how retrofit contractors and their clients select a solution, particularly for story-and-a-half homes. We are especially interested in the conditions, methods, cost, and marketing of exterior insulation roof retrofits in the context of effectively solving ice dam problems.

Background Info:

1. Interviewee Name: Curt Stendel

2. Interviewee Title: President

3. Company Name: Panelworks Plus, Inc. (PWP) (http://panelworksplus.com/index.html)

4. Location of Business: St Francis, MN

5. Complete scope or range of company services: SIPs for new construction and retrofit; Panelworks Plus is an independent dealer/distributor of SIPs and retrofit panels manufactured by Extreme Panel Technologies, Inc. of Cottonwood, MN (www.extremepanel.com) working with homeowners, builders and remodelers, often providing full panel installation or on-site training to ensure proper installation.

6. Years in energy retrofit business: 10 years (since 1999 residential; incorporated 2001 with Extreme Panel). Panelworks Plus was incorporated in 2001 based on Curt's background of working with SIPs in agricultural, commercial and residential applications since 1980. To date, work is almost equally divided between DIY homeowner/contractors and licensed general contractors.

7. Number of "ice dam" retrofits completed in last 5 years: the ice dams of 2010-2011 is driving PWP's recent surge in roof retrofits—5 last year alone

Questions:
When a potential client comes to you to with an ice dam problem:

1. What information do you need before proposing solutions to the client?
   a. Assessment/inspection form - no
   b. Pre-work testing (blower door, infra-red imaging, etc.)—sometimes, when working with a home performance contractor/consultant, but not on his own (Curt).
   c. Client financial "aptitude"—not really; they come to PWP because they have heard that they work

2. What is the full range of ice dam solutions your company provides? PWP only does retrofit panels, either two-sided or one-sided nail base panels.

3. How would you rate each of the above based on:
    a. Relative cost
    b. Ease of construction/feasibility
    c. Durability
    d. Hygrothermal performance (combined energy and moisture management performance)

    Curt believes that retrofit panels are competitive on all fronts with any other roof retrofit or ice dam solution. I am following up with Curt to see if he can give us a single estimate or range for installed cost per square foot of his retrofit panels.

    Curt is just starting to keep track of the reduced energy bill impacts of his roof retrofits. He is calculating therm usage based on heating degree days. So far, an estimate of the impact of his work is about a 15% reduction in gas use for space heating. He wants to add information on any reduction in electrical use for space cooling.

    Two important notes on Curt's work on roof retrofit panel installations:

    1. PWP pays very close attention to perimeter air sealing anywhere that our panel installation is in contact with the existing structure as well as between the individual panels.
    2. Curt deals with the increased fascia height of exterior panel installation on roofs with a double fascia or, if the depth of panels precludes the double fascia, he will plumb-cut existing soffit to eave wall and rebuild new soffit, essentially making the eave walls one or more courses of wall cladding "taller."

4. What resources do you use to explain the phenomenon of ice dams to your clients?

Just verbal so far; ice dam roof retrofits are a new line of business for PWP and they are just starting to develop information and marketing resources targeting this work.

5. What are the factors that drive which solutions you propose
    a. Building details (roof complexity, extent of the ice dam problem, age of roof cladding, roof pitch)
    b. Client budget
    c. Sequenced or planned previous or future work

    The thicker the panel, the more complex installation is; the presence and number of valleys also affects installation, more than any other roof feature.

    i. Panel cost will vary with the thickness of the panel but the bigger issue of cost is driven by the complexity of the roof. Since panels are cut to fit on site, the panel cost will not change much but labor to install panels on steeper roof pitches, valleys, dormers will impact the total retrofit project cost.

6. Check out the 5 common roof types on the last page of this questionnaire:
   a. Is there one or two that you most commonly deal with in ice dam work?
   b. Is there any relationship between roof type and which solution you propose?

   Quite a bit of PWP's work to date has been cabin-type upgrades, often with fairly simple roof configurations, but including plenty of valley work.

   a. Our work to date has included rather simple 4/12 pitch roof planes to a very complex 12/12 pitch roof with valleys, transitions, both gable and shed dormers and a porch roof with both a hip and a valley on a 130 year old farm-house.

7. What sort of post-job evaluation or results do you gather?

Nothing yet, unless PWP's work happens to be with a performance contractor/consultant.

Only one project has involved any sort of pre- and post-work performance testing and this one was just an abovegrade wall retrofit, not involving the roof.

But PWP strongly recommends to their clients that they start and end by working with a home performance contractor.

8. How often are mechanical system changes/retrofits associated with your building envelope work (adding spot exhaust ventilation, whole-house ventilation, or radon mitigation)?

   This is not part of PWP's business model or expertise. But PWP does, however, strongly recommend that their clients add a home performance contractor to their projects.

9. How do you specifically market your ice dam/roof retrofit solutions, especially in the context of what you consider to be the competition for effectively solving ice dam problems (e.g. heat tape, roof raking, installing a standing seam metal roof—complete or just the eaves)?

   Just now working on a marketing 2-pager on ice dam roof retrofits and Curt has offered to send this to us just as soon as the copy is finalized. Extreme Panel also has a new flyer out regarding retrofit panels.

10. Can you provide documentation for one or more of your recent ice dam-driven roof energy retrofits:
    a. Inspection/assessment
    b. Before/after images (digital/IR)
    c. Construction details
    d. Pre-/post-testing results
    e. Cost details (labor/materials/profit; bid/cost-plus contract, etc.)

    Curt is working on getting us details, including photos and cost, for his David Miller project.

11. What do you think is the single most important or influential change that would significantly promote a complete exterior insulation roof retrofit in comparison to other potential solution sets for ice dam problems in existing homes?

    Education! Curt is convinced that work such as this project (the NorthernSTAR overcoat project, and conferences like the upcoming Duluth Energy Conference (www.duluthenergydesign.com/), at which Curt will be presenting on his retrofit panel projects.

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