# Closing the Retrofit Gap: Integrating Existing Windows with New, Thick Continuous Insulation

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**ABSTRACT**

The Pacific Northwest National Laboratory (PNNL) conducted a total of 51 field demonstrations to test the real-world costs and benefits of adding continuous insulation to an already planned and budgeted re-siding project. Site observation and contractor interviews confirmed researchers' expectations: for existing windows remaining in place, the challenge of integrating all control layers of the thicker wall assembly can be a make-or-break decision point. The typical approach is jamb extension "picture frames" using dimensional lumber thick enough to hide the full depth of the added insulation layer. Some re-siding crews are uncomfortable with carpentry, though, and lumber constitutes significant thermal bridging. To provide additional solutions and increase consumer choice, the team worked with manufacturers and installers to brainstorm and develop alternative means and methods for architectural trims that are thermally broken, well-drained, properly ventilated, and support inexpensive, non-destructive future window replacement. Novel methods using insulated materials intended for parallel purposes were mocked up and demonstrated, as well as several two- and three-part bent metal solutions. Aluminum coil stock and metal brakes for bending profiles are ubiquitous on re-siding jobsites and installers are typically adept with this work, providing another alternative to lumber framing. This paper will cover the challenges and opportunities and outline PNNL's installation guidance to reduce risk and increase profits for re-siders considering the practice of adding insulation when re-siding.

## Introduction

The U.S. Energy Information Administration's most recent Residential Energy Consumption Survey (EIA 2020) establishes that approximately 70% of the residential building stock in the United States has inefficient windows, insulation, and air sealing compared to residential new construction performance. These conditions contribute to high utility bills and poor comfort for millions of citizens.

Continuous exterior insulation (CEI) for walls is a known solution in residential new construction since 2006 or before and is especially popular in colder regions (Lstiburek and Baker 2015). While some remodelers and re-siders offer CEI to their customers, uptake in the retrofit market has been relatively slow with plenty of growth opportunity (Cort et al. 2022). Studies and field demonstrations by building science researchers have identified opportunities to reduce complexity, time, and risk, while improving durability (Antonopoulos et al. 2022) in hopes that novel solutions may provide contractors and installers with the confidence needed to use the practice. Much of this research has focused on the opaque wall component, and frequently identifies window trim-out and control layer integration as a challenge that deserves attention. This paper identifies some of the most common approaches and challenges encountered when trimming out the window during re-siding jobs and discusses some alternative

approaches PNNL is researching to enhance the integration of window-wall control layers while streamlining the process and reducing retrofit costs.

## Background and Literature Review

In 2022 Pacific Northwest National Laboratory (PNNL) launched a project called Adding Insulation when Re-Siding. Simultaneously, the New Jersey Institute of Technology launched "Re-side Right" (Liaukus 2023). Both research projects used field demonstrations, wall assembly testing, and industry engagement to identify and overcome barriers to adding CEI for home retrofits. PNNL's project is particularly focused on cases where the homeowner has already committed to and budgeted for a re-siding project, which means the exterior walls are fully exposed and CEI can be installed at a relatively modest incremental cost to the overall re-siding project since most of the time and labor to remove old siding and prep the house for new siding would have been included as part of the original project.

PNNL documented over 50 installations in 20 cities and 10 states with 19 contractors and the project is in the process of gathering empirical, subjective, and observational data to validate that the benefits determined through previous laboratory tests, energy and economic analysis, and case studies can be duplicated with a variety of conditions and at scale for real-world homeowners and contractors.

### Synergistic opportunity

The goal of the field demonstrations is to improve the wall's thermal, air, and moisture performance at the time of an already planned and budgeted re-siding job with the least added cost, complexity, and time for the best performing outcome.

For an average 2,500 square-foot U.S. home, re-siding costs alone are between $10,000 and $30,000 for vinyl siding, installed, and up to $45,000 to $50,000 for masonry or other premium choices (BPI 2026). Freedonia Group projects that the re-siding market size for 2027 will be 84.7 million squares (100 $ft^2$ of siding material) valued at $10.6 billion (Freedonia 2024). Presuming approximately 25 squares per house on average, that represents over five million homes. For the past decade, the average number of new construction housing starts in the U.S. is typically between 1 and 1.5 million (USCB 2021), so the number of siding retrofits is as many as four million each year.

Depending on material choices, installation quality, and weather conditions, siding can typically last many decades. Companies throughout the nation that offer siding replacement frequently estimate 20 to 50 years of use-life for non-cementitious materials[1]. Yet, according to an online article in The Zebra, the average length of homeownership is eight years and the median tenure is 13.2 years (Meyer 2024). Given the short tenure and the varying age of existing housing stock, many homeowners will consider re-siding at least once. The most common reasons to replace siding (Harris 2022) are to repair damage or to update appearance, followed closely by energy efficiency and maintenance (the survey question allowed multiple responses).

[1] Sampling from the internet, March 2026: https://homegeniusexteriors.com/genius-blog/how-long-does-siding-last/; https://mmroofsiding.com/blog/how-long-does-siding-last/; https://www.visexterior.com/blog/how-long-does-siding-last.

Additionally, according to research by Home Innovation Research Labs, homeowners are 3 times more likely to add insulation to their house in the first year they own it than at any other time[2].

When an additional layer of CEI is combined synergistically with a re-siding job that the homeowner has already committed to, the incremental investment of about 15% to 25% compared to the original re-siding budget, but yields utility bill savings that exceed a standard investment (Present 2024) as well as comfort and noise reductions. Every year there are millions of homeowners positioned to benefit from adding insulation when replacing siding.

**Why are windows a potential pain-point?**

Contractors, siders, insulators, and window installers have long identified window flashing and integration of the window with the wall layers as a challenge, even for new construction using well-understood materials and methods. Avoiding thermal bridges and gaps, preventing bulk water intrusion, and eliminating air leaks requires building science understanding and attention to detail, as well as a good imagination.

Shah, Bhandari, and Tang point out that residential buildings offer unique opportunities for reducing energy consumption and thereby lowering utility bills (Shah et al. 2026). But they also note that windows can be a weak link, because they make up 15–40% of a typical building façade (opaque and transparent wall elements) and the performance of windows installed in walls with CEI has not been well evaluated. They thermally analyzed four traditional (access to rough opening) window installations in walls with CEI and determined that the 12-in. (305 mm) wide perimeter area surrounding each window suffered a reduction in thermal performance of between 7.6% and 34.5% compared to an opaque wall of the same construction. In addition to this flanking loss, the team identified inherent challenges with air leakage and moisture due to poor workmanship and issues related to incorrect specifications for structural, moisture, and bulk water performance needs.

The proposition becomes much more challenging when the existing windows remain in place, and all control layers must be addressed at the surface, rather than within and lapping the rough window opening as in new construction. The most likely installers for the proposed strategies[3] are re-siders, remodelers, or homeowners who prefer the Do-It-Yourself (DIY) approach, so consideration of their level of experience and training and the typical tools they are likely to have on hand is key.

Due to the high cost of re-siding, many homeowners do not have the ready cash necessary to also replace windows, although, as with CEI, the predicate of a re-siding job is the prime opportunity to upgrade windows as well, due to access and simplicity. Additionally, heating-dominated regions (i.e., U.S. climate zones 5 and above) will probably benefit from – and possibly need, from a vapor barrier standpoint – at least two inches of CEI. This means that windows that are currently flush with the wall surface will become recessed with respect to the added thickness, which poses the risk that standard J-channel[4] and other commercially available trims will no longer work without modification. Anecdotal results from the field demonstrations

[2] Hudson, E., Home Innovation Research Labs. Unpublished analysis based on various surveys and focus groups.
[3] This strategy presumes the addition of one or more inches of CEI taped and detailed as the air and water control layers, in addition to its role as the thermal control layer. Alternately, a secondary weather resistive barrier (WRB) may be included.
[4] J-channel is a standard, “off-the-shelf” trim available at most construction retailers. This “J-shaped” piece of trim includes a flange that is shaped and sized to overlap and hide the cut edges of siding where it terminates at window and door edges to improve aesthetics and shed water.

revealed that contractors engaged to provide project estimates sometimes resisted bidding thicker CEI due to these complexities, and some were reluctant to bid even on one inch of CEI, due to lack of experience or liability concerns.

### How Are Existing Windows Trimmed Now?

The most typical approach to trimming existing windows in walls with newly-installed CEI is standard, off-the shelf J-channel and trim profiles, but these only work when the combined thickness from the plane of the sheathing (or the face of the window framing, depending on the profile) is one inch-or less. So even some walls getting only a one-inch thick CEI layer may not be suitable for off-the-shelf trim materials if windows are already flush or inset.

When the added thickness doesn't allow for standard trim, the likely solution is jamb extensions–essentially a surface mount "window frame" made of dimensional lumber–that may be wrapped in aluminum coil stock, which is ubiquitous on many siding jobsites. Additionally, in PNNL field demonstration interviews many contractors reported that bending metal using a jobsite brake is a favorite task due to the opportunity to think creatively, problem-solve, and see immediate, tidy results.

## Methodology

### Study Objectives and Research Questions

The PNNL field demonstration project began in late 2022 and will conclude in August of 2026. The project's overarching goal was to understand how typical contractors and homeowners approach the concept of adding insulation when re-siding. While the primary research questions for the project surrounded the time and costs associated with adding insulation when re-siding, another key focus quickly became the questions associated with the window to wall interface.

The following topics were frequently brought up by contractors, installers, and other decision makers:

- Identifying non-standard existing conditions and geometries or complexities that require early planning
- Understanding when thicker insulation is recommended
- Understanding the impact of adding thickness to an exterior wall
- Accurately bidding a project
- Saving time and cost
- Knowledge and availability of needed materials and components (beyond what a standard re-siding project requires)
- Optimizing performance and durability
- Knowledge of building science and control layers
- Staff training and oversight
- Aesthetics
- Facilitating future window replacement
- Energy and non-energy benefits

## Study Initiation

Under federal law, study that includes direct contact with homeowners is considered "human subjects research." The research team worked with the PNNL Human Subjects Protection Program to develop a detailed research plan that deals fairly, plainly, equally, and openly with all human subjects. This plan included an informed consent form with details and goals of the study, the participant's role in it, a description of how we would protect their personally identifiable information (PII), how they would be compensated for participating, how they can ask questions of a reliable, knowledgeable third party, and how they can remove themselves from the study without penalty, if desired.

The PNNL field demonstrations were designed to respect and learn from the relationship between contractors and homeowners, observing as they collaborated and relying on the professional skills and knowledge of the contractors, with PNNL and industry subject matter experts available to answer questions and provide technical guidance if requested.

Initially, homes were recruited in the Mixed Humid region of the United States – where a 1-inch layer of CEI is appropriate for both thermal and vapor retarder considerations, and because 1-inch of added thickness was presumed to be the easiest first effort for contractors new to the practice. The expectation was to engage contractors interested in expanding their skills and scope and provide them with study information to share with prospective clients.

The project targeted a minimum of 50 field demonstrations with narrow criteria to achieve a level of uniformity. As recruitment proceeded initial constraints were sometimes waived to achieve target participation and eventually to provide a wider variety of solutions, since we learned early there is no reliable "average" situation.

## Industry Participation

The project included an industry advisory group that has met five times so far and provided insights into re-siding and remodeling, recommendations for best practice, review of installation guidance documents, marketing insights, and industry context. Advisory group participants included experts from companies that manufacture and/or distribute rigid foam plastic sheathing, fibrous rigid board sheathing, various types of siding, flashings of all types, and fasteners, trims, glues, caulks and tools.

Engagement with contractors and other stakeholders occurred through mass emails to business addresses, cold calls, word-of-mouth, and various online or in-person exhibits, demonstrations, and presentations throughout the country.

## Data collection and analysis methods

The team gathered both numerical data and observational findings as part of this study.

### Empirical.

- Site observation: photos and videos, ad hoc conversations
- Before and after blower door (with infrared photography if conditions allowed)
- Utility data: 1-yr pre-upgrade, 1-yr post-upgrade
- Smart thermostat for indoor conditions and equipment run-time
- Local weather station data for energy analysis and utility bill analysis
- Material and labor costs

**Anecdotal/subjective.**

- Pre- and post-upgrade survey design
- Comfort, noise, other non-energy benefits
- Satisfaction, perceived investment opportunity

**Interviews.** Contractors were interviewed before and after the installation, and sometimes several months later to document updates or changes in opinion. Homeowners were interviewed directly following the installation and again after they had lived with the upgrade for about a year. The following are example topics of discussion:

Contractors

- Constructability
- Perception of risk or opportunity
- Adoptability
- Greatest needs
- Knowledge
- History of this work
- Plans to adopt the AIRS practice

Homeowners

- House details, ownership background
- Perceptions of comfort, energy efficiency
- Motives, expectations for participation
- Decision-making considerations
- Expectations of contractor, choice metrics
- Perception of the building industry
- Preferred information sources

**Timeline.** The upgrades for the last of the 52 housing units was completed in September of 2025. All project costs, utility usage analysis and contractor and homeowner insights will be compiled and published by the end of August 2026.

## Results: Comparing Window Trim-Out Options

PNNL installation guidance was reviewed by the advisory group and included posters and slide decks with schematic and photo examples of "best practices" that are typical in the field. For existing windows remaining in place, the guidance included:

- Clean and patch sheathing; fill gaps around window frame or flanges with insulation, foam backer rod, or low-expansion spray foam; apply self-adhered or liquid-applied flashing at all four edges, lapped up the orthogonal frame projection; install a metal counter-flashing at the window head and seal leading edge with building tape, rolled to activate adhesive.
- If desired (or needed for non-tapeable CEI), install weather resistive barrier (WRB) over sheathing, shingle lapped from low to high to direct water out and down, and taped and detailed as both air and water barrier; leave a small gap around window to ensure that construction tape that spans from WRB to window frame can adhere to the sheathing surface, lapping from WRB across the gap and to the sheathing surface, and lap up the window frame projection ¼ to ½ inch. Self-adhered and liquid-applied WRBs were listed alternates.
- Install rigid insulation boards with clean-cut edges tight to the window frame using cap nails of sufficient length to meet International Residential Code (IRC) fastener schedules, and tape and detail as air and water barrier. Begin below the window and finish upwards, ensuring all tape is shingle-lapped and mechanically rolled to activate adhesive.

- If the board insulation is tapeable, use construction or flashing tape to integrate the exterior plane of the insulation with the window trim (jambs) and new head flashing (header) of window. If WRB was installed, leave the area below the window untaped to encourage draining.

Figure 1 shows typical guidance for windows that could accommodate the proposed additional thickness without jamb extensions.

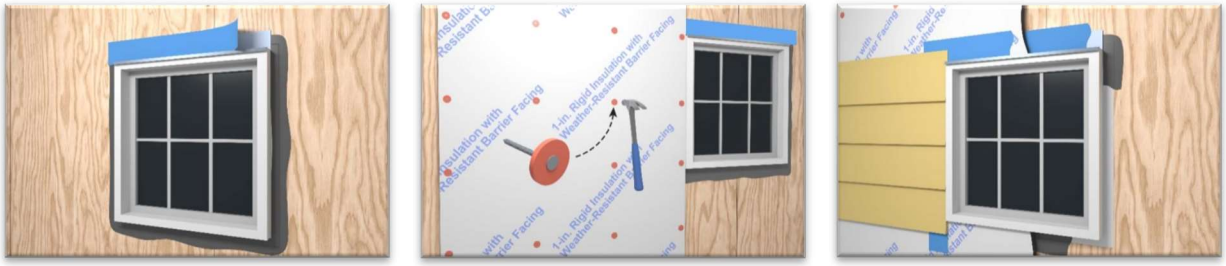


Figure 1. Installation guidance for window control layers when new wall thickness can be accommodated. *Source*: PNNL, 2023.

## Full Window Replacement

Early discussions and field observations made it clear that projects that could afford to also replace windows were not flagged by contractors as complex or uniquely challenging. They simply treated it as they would new construction since after removal of the old siding, the entire rough window opening was accessible. In that case, they could cantilever the new window slightly to make up the difference between the extra thickness and the frame projection, or use 1x6 or wider lumber to "buck out" the opening so that the window's flanges against the buck hold the exterior window surface at the expected projection in the new wall assembly (Figure 2).

Figure 2. Window install where existing window is removed and lumber buck is placed to accept replacement window to meet new wall thickness. *Source*: PNNL, 2023.

## For CEI One Inch or Less and No Window Replacement

For integrating new siding and up to 1-in. of CEI with windows that remain in place, the most common solution seen in the field is to use off-the-shelf trims, moulding, and J-channels, possibly with minor modifications (Figure 3). It was not uncommon to encounter frame projections of approximately ¾-in. where a standard J-channel could slip into place, or a deeper

projection that could be accommodated by installing the J-channel slightly proud, losing only a small strip of connection with the window frame projection but still covering the cut edge of the insulation board. Some supply houses can also special-order J-channel with a deeper flange, though in general, contractors don't anticipate this need and a change in planning would have to be adopted for it to occur smoothly.

Figure 3. Typical window field installation when new wall thickness can be accommodated with standard trims. *Source*: PNNL, 2023.

**For Thick CEI and No Window Replacement**

For CEI layers exceeding ¾-in., the typical solution was to cut jamb extensions out of dimensional lumber on-site to each window's aspect ratio. Some contractors preferred to install these four pieces independently, but it was more common to assemble these pieces on the ground into a "picture frame" configuration, lift the finished assembly into place, and attach it to the sheathing.

Adding the bent metal wrap with the jamb extension in place covers fastener heads and allows the installer to work from the bottom up, so that jamb pieces lap the sill tabs, and the header laps the jambs, for reliable bulk water control. Wrapping in metal protects the wood from weather and visually masks the lumber's imperfections. If they were to sand, prime and paint these jamb extensions, it would take more time, trouble, and mess. Additionally, they would feel compelled to cut 45-degree corner angles and butt them, which requires precision for a clean fit. Covering with metal allows them to straight-cut and then butt-join all four corners of the lumber. Then the metal wrap for the jambs can extend full-length, but the metal header wrap can be cut at 45-degrees on each side and then lap the jamb covers without gapping, even if the cut is not perfect. J-Channel or other cap is still necessary to shield the siding edges.

Installers reported that wrapping lumber jambs in metal is an obvious solution, since they already have the coil stock and bending brake on hand for other tasks. Conversations indicated that bending metal is a satisfying task because it provides a crisp appearance, matches other custom trims on the job, and can easily hide non-square conditions.


Figure 4. Window treatment where the edge of the CEI layer butts to a new lumber jamb extension that is wrapped in custom bent metal coil stock to provide a finished look. *Source*: PNNL, 2023.

Lumber is a substantial thermal bridge and doesn't drain well. While 2x4's could be ripped lengthwise to reduce the contact area of the bridge, this is seldom done. Chop saws and skill saws are common on re-siding jobsites, but table saws or guides to ensure clean, straight, uniform longitudinal skill saw cuts are less likely. Because metal wrap is typically attached with caulk or construction glue, future access to those windows requires destruction that will likely prevent re-use of the custom jamb assembly and waste the materials and require redundant effort to trim out the new windows.

**Alternate Window Trim-Out Approaches with Thick CEI and No Window Replacement**

Budget often drives the decision to delay window replacement, so adding the complexity of a high-performance built-up solution that can't be removed without destruction wastes not just the time and materials invested but also creates more waste and cost in the future to modify and then re-build the neighboring materials–siding and CEI. The window trim-out scoping task of this research project encouraged contractors to "think outside the box" to suggest alternatives, and to react to innovations suggested by PNNL researchers. The team developed the following performance criteria for a new solution:

- Build on accepted practice. It should build on common practices, use common tools, and not stray far from current installer comfort and expectations.
- Cost Savings. It should have the ability–at scale–to rival the cost of the incumbent practice, or to provide secondary cost savings through ease, speed, or additional value.
- Faster Installation. It should reduce complexity to increase installation speed and/or combine performance attributes to reduce the number of installation processes.
- Insulative. It should either be made of material with an appropriate R-value (from R-3 to R-6, overall) or be made to accommodate installation of the CEI layer directly up to all window framing edges, reducing or eliminating thermal bridging.
- Durability and control layer integration. It should provide a straightforward, reliable method of integrating between window and wall layer(s) to control air, moisture, bulk water, and thermal flux that can last for years and/or is easily "touched up" at intervals to maintain like-new protection.
- Support future window replacement. Preferably surface-applied and removeable so that the entire window assembly including flange can be exposed in the future with no–or only minor–destruction. The goal is to 1) provide high quality control layer performance

even with the existing, inadequate windows, and to 2) facilitate fast, seamless future window replacement when the budget allows, and 3) be re-usable not just once, but potentially multiple times.

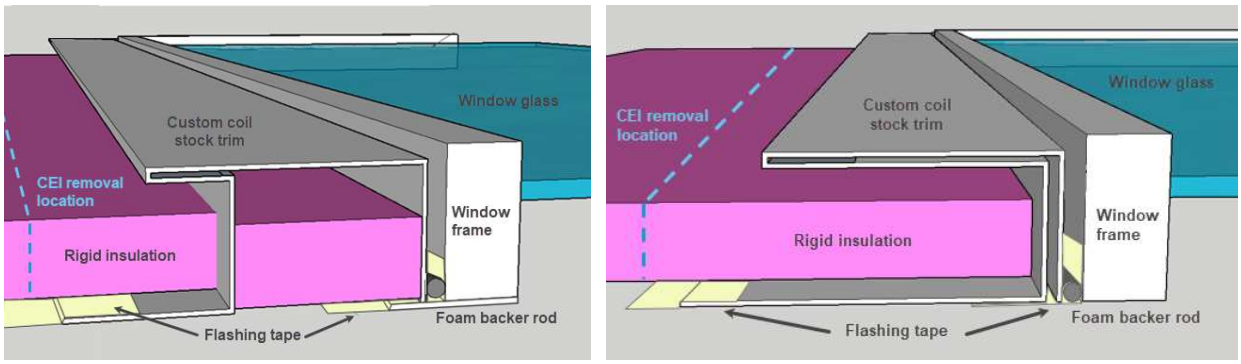
## Results

The ability of a window trim-out solution to "support future window replacement," is perhaps the most important of all the proposed performance criteria. The following solutions were developed over the course of the project and socialized with contractors to determine viability, including further development with schematics and physical samples. For all versions, the existing window would be surface-flashed with best-in-class tapes and methods and provided head flashing with a drip edge.

### Drainable, Dryable, Removeable Bent Metal Coil Stock

This solution is a completely field-constructed trim system that utilizes the materials and tools already on a siding or re-siding jobsite and favored by typical siding installers: aluminum coil stock and a metal bending brake.

**Initial concept.** The research team initially imagined simple profiles that took up more space than J-channel and allowed the CEI to extend nearly to butt the window frame (Figure 5). The first design created an independent channel for a flanking portion of CEI, and the second was simpler. But, when properly flashed, for both solutions the window flanges were buried and required destruction of CEI and siding for removal. Both profiles were single pieces and required complex bending maneuvers.




Bent metal trim profile #1 Bent metal trim profile #2

Figure 5. Early concepts of a drainable, dryable, bent metal trim solution, that were later improved to simplify future window replacements. Yellow denotes typical flashing tape. Dashed lines indicate where siding and CEI would need to be cut and removed to access the full rough opening for future window replacement. *Source*: PNNL, 2023.

**Refined concept.** The design was improved by the input of an expert in exterior remodeling, who also professionally demonstrates various construction tools, including metal brakes. The innovation is multiple parts that allow for piecewise removal and better draining and drying (Figure 6). The three pieces are 1) a custom F-channel, sized to receive the chosen CEI thickness, flashed to sheathing and mounted about 2 to 4 inches exterior of the window flange–the typical installed extent of self-adhered flashing tape, 2) a custom J-channel, sized to receive the chosen siding thickness, flashed to the installed CEI, and 3) an architectural cap that clips to

the J-channel and spans across the flanking section of CEI below to the window framing. The cap's orthogonal flange is either installed tight to the edge of the window framing or snugged into the thin channel common to many vinyl windows. This approach allows for a variety of appearances, and each additional crimp in the longitudinal pieces adds strength.

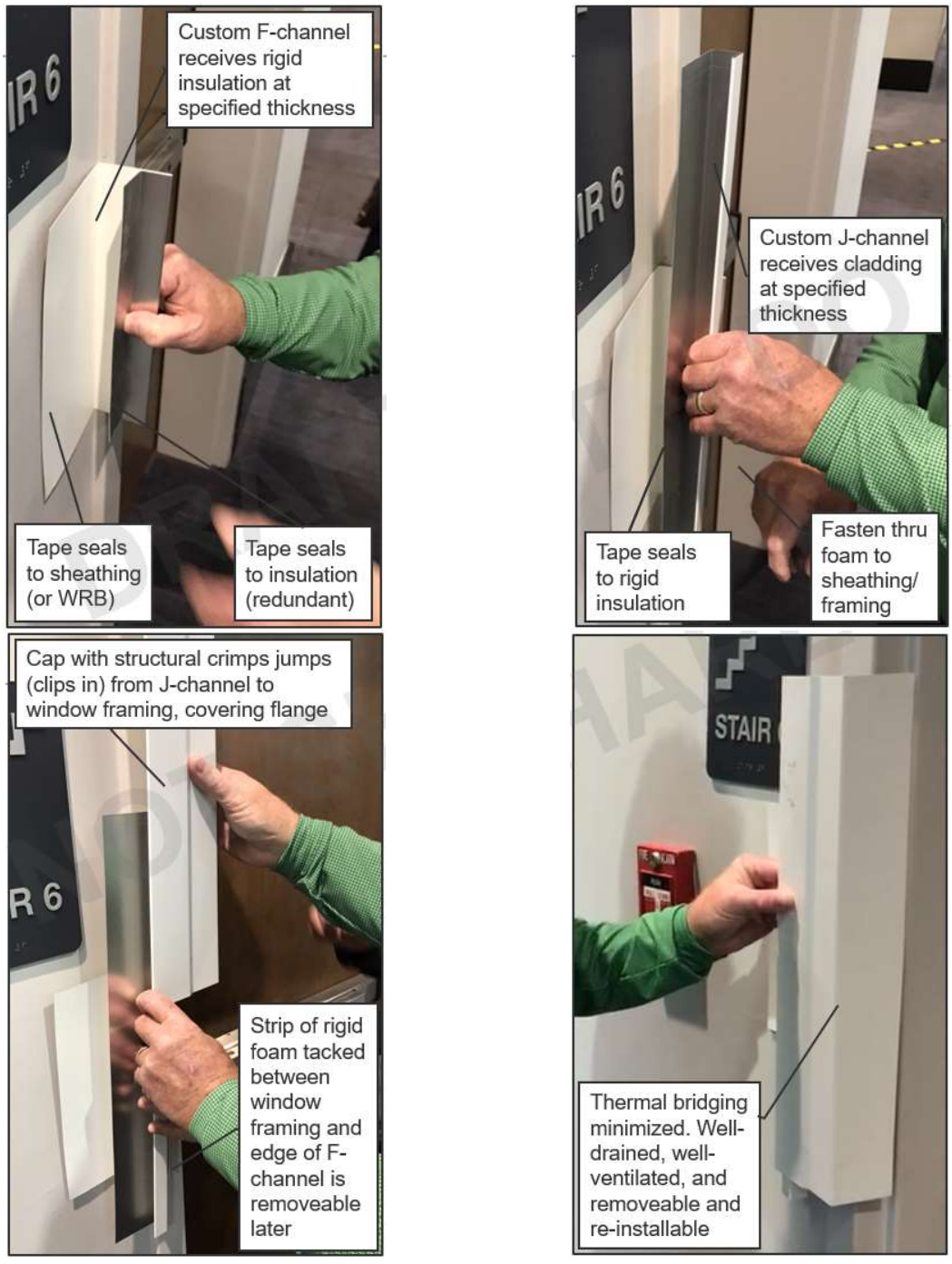



Figure 6. Refined mockups for a drainable, dryable 3-piece, bent metal trim solution. CEI receiver butts to separate CEI layer, custom J-channel butts to siding. Three-piece assembly creates the ability to remove architectural surface cap for access to separate CEI layer, without disturbing siding for future window replacement. *Source*: PNNL, 2024.

**Minimized concept.** The design was later tested without the custom F-channel by a contractor who felt three pieces might be off-putting to smaller operators. (Figure 7).

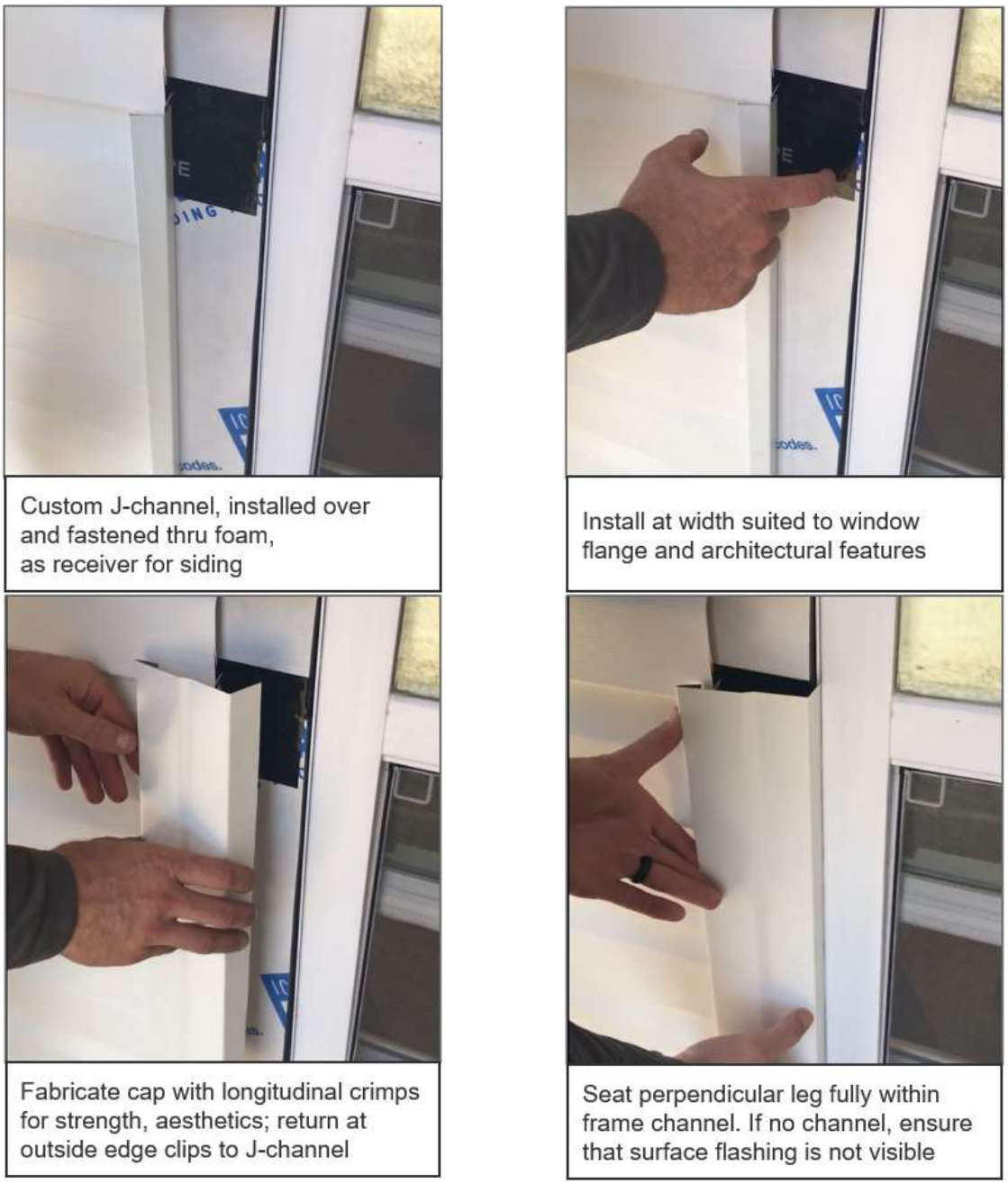



Figure 7. Trial simplification of bent metal trim solution as two pieces, utilizing typical window framing channel, still well drained and ventilated and the architectural cap profile can be customized to meet aesthetic and structural goals. This approach requires that the flanking section of CEI be cut back to expose window flanges to remove the window, which can be saved and re-installed, but future window replacement is not quite as seamless as the original 3-piece design. *Source*: PNNL, 2024.

The two-piece simplification, though still well drained and ventilated, does not include the custom CEI receiver, so the installer of a future replacement window will need to cut back the flanking section of CEI to expose the flanges for window removal. After the new window is

in place, the flanking CEI section must be reinstalled, and limited access at the edge of the siding receiver may complicate new taping and integration to existing CEI. This minimalist version is slightly faster at the time of initial installation but does not provide quite as a seamless a process for future window replacement. As with the three-piece solution, this approach allows for a variety of appearances and can be strengthened with additional longitudinal crimps.

**Pre-fab, Insulated, Site-Assembled, Surface-Mounted Window Trim-Out Kit**

The research team also proposed a second solution that would be accessible to crews without access to a metal brake, and even to experienced homeowners who prefer the "do it yourself" approach (DIYers). This innovation could also potentially be used in commercial buildings. Windows inevitably need to be replaced over time, which results in a messy excavation effort that destroys the existing integration of control layers with walls, and complicates flashing re-construction, especially if there is a layer of CEI in addition to siding.

This second proposed solution is a system of pre-fabricated, insulated, straight and corner components designed for field-modification and assembly, surface-mounted, and removeable and re-installable to support multiple future window upgrades (Figure 8). The final "picture frame" assembly would be site-customized to each window, rigid and removeable as a single, stiff assembly for trouble-shooting flashing application and future window replacement. A variety of product thicknesses would accommodate any combination of CEI and siding. The product components would be sized to cover from window frame to well past window flanges so that removal of the entire, stiff, 3-dimensional, surface-mounted assembly provides complete access to the full extents of the rough opening, window framing, and mounting flanges to facilitate future window replacement without disturbing existing wall layers. Properly designed, this solution would be suitable for both new construction and retrofit. This concept includes the following criteria:

- Factory fabricated
- Site-assembled to custom aspect ratios with minimal modification, easy straight cuts, and universal pre-fab corners
- Surface mounted and 3-dimensional; stiff and durable with the support of shiplap, mortise and tenon, or other "hideaway" joinery
- Removeable and re-installable (in one piece) for multiple future window replacements
- Pre-finished with a weather-resistive coating
- Installation process meets building science principles for control of moisture, air, bulk water, and thermal transfer
- Integral bulk water control like headers with drip edges and sills with slopes
- Integral profiles to eliminate secondary trim or J-channel for seamless connection and protection of chosen siding.

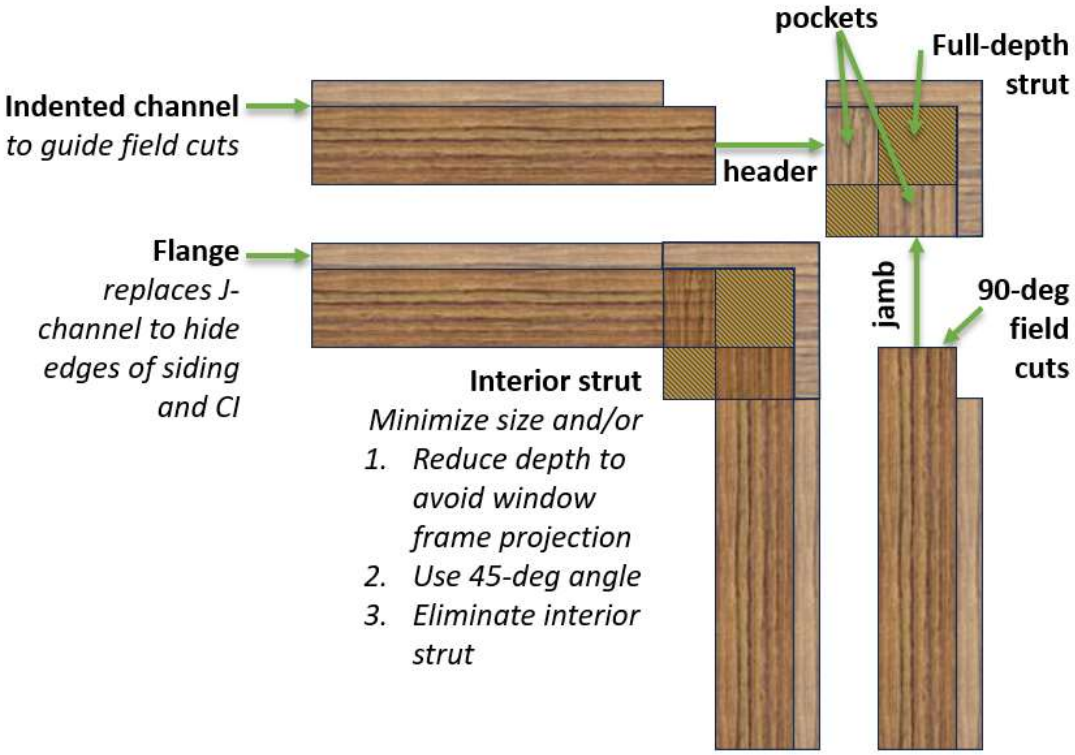



Figure 8. Proposed pre-fab, insulated, and weather resistive straight and corner components for custom assembly on-site. *Source*: PNNL, 2023.

This solution can be decorative or plain to meet any architectural style. Various moderately dense insulative materials would qualify, so long as they can be molded or milled with pockets or laps to receive and hide cut ends of straight jambs, sills, and headers. Straight pieces are preferably universal (appropriate in all four orientations), easily field modified with straight cuts, and the pockets or lap caps in the pre-fab corners would have a bit of "slop" to adjust for potentially out-of-square field conditions.

This approach requires collaboration from a suitable manufacturer to confirm fabrication, assembly, and structural performance targets, as well as to explore various profiles, colors, and textures to meet architectural expectations.

## Discussion, Conclusions, and Next Steps

Although the CEI retrofit field demonstrations carried out by PNNL represent only a small fraction of the wide-range of building sizes, geometries, conditions, and installer skills on a retrofit site, this research advances the solution options for common construction challenges that are likely experienced in a large portion of home envelope retrofit projects.

CEI poses unique challenges for window trim-out and effective control layer integration. Solving these challenges–especially for retrofit situations where windows will remain in place–is an opportunity to provide options that can increase speed and durability, reduce complexity and cost, provide ready, uncomplicated access for maintenance, and facilitate future window replacement. Both the bent metal and the pre-fab system described here represent viable solutions with the potential to capture industry attention, with opportunities for streamlining and cost-compression, while improving performance.

The bent metal multi-piece solution shown in Figure 6 is undergoing additional research under current project funding, with experts engaged to solve challenges such as corner connections. Additional benchtop and field demonstrations are planned. Project deliverables include installation guidance products such as videos, posters, and schematics. Bending brakes to fabricate custom trim are ubiquitous on both new construction and retrofit jobsites, both residential and light commercial, and the goal is to socialize this ad hoc solution in all appropriate venues.

The pre-fab, insulated, surface mount solution shown in Figure 7 is being studied under separate funding as part of a "feasibility" exercise in partnership with the developer of a novel insulated wall panel. The scope of work includes a market landscape analysis, refinement of product geometries and specifications, construction mock-ups, and one or more field demonstrations. The panel manufacturer partner has already optimized materials and fabrication methods–including a proprietary weather resistant coating–so that the new window trim-out kit will "close the loop" on a coordinated product offering: a complete, unified system that ensures a high-performance connection between advanced windows and the insulated wall system. If successful, the design could be adopted/modified by other manufacturers using a variety of different materials and finishes.

The original motivation of this research was to affordably solve control layer integration challenges that were identified in PNNL's Adding Insulation when Re-Siding field demonstrations where CEI was added as part of a re-siding job. Many millions of homes that are replacing their siding could benefit from these innovative trim-out approaches when their project includes CEI and the existing windows remain in place. The proposed solutions presented in this paper could provide lower cost and streamlined retrofit options not only to the millions of homes that are being re-sided but also to the million-plus houses built new each year in the United States. In addition, both innovations are suitable for the large subset of light commercial buildings with "punched windows" (as opposed to storefront or curtainwall windows). The added benefit of non-destructive removal and re-installation will translate to less time, cost, and disruption, which means that building owners can more easily and quickly adopt new, high-performing glazing and framing window technologies as soon as they are available, smoothing the path to high-impact envelope energy upgrades.

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