Adding Insulation when Re-Siding: A Wall Retrofit that Ticks All the Boxes

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ABSTRACT

The Pacific Northwest National Laboratory (PNNL) Adding Insulation when Re-Siding (AIRS) team has been testing contractors' ability and appetite to offer their re-siding customers the addition of at least 1-inch of rigid exterior insulation, taped and detailed as the air and water barrier to yield excellent thermal comfort, noise control, and energy savings. As added scope to a re-siding project, AIRS can add 20% to 30% more cost, but the upgrade will never be easier or cheaper than at this time. A subset of non-profit housing organizations noted that many of the houses in their programs have zero wall insulation. These non-profits typically choose drill-and-fill dense pack cellulose, but leaving wall cavities empty in favor of maximizing the exterior insulation offers additional, unique advantages for vulnerable communities, including 1) flood resilience; 2) freeze protection for pipes; 3) flexibility in trades coordination; and 4) less disruption and more security for children home alone during the energy upgrade. This paper presents preliminary results from the first two AIRS sites, covering rationale, cost, performance, and installation, as well as general observations from all participants. Overall, we find good interest from homeowners, remodeling contractors, and local non-profits that provide low-income housing, but less interest from re-siding contractors, the cohort we initially hoped to recruit as champions. Of homeowners who chose to participate, most cited the increased comfort afforded by AIRS to be their most positive initial reaction, followed by lower utility bills; contractors often cited unwanted complexity. The project is ongoing.

Introduction

The U.S. Department of Energy has established a Blueprint for decarbonizing U.S. buildings (EERE, 2024), which lays out a national strategy for aggressively reducing greenhouse gas emissions and to align with the Biden-Harris vision of a net-zero emission economy by 2050. Critical to the success of decarbonizing the housing stock requires a vast improvement in the energy efficiency of existing buildings with the target of reducing on-site energy use intensity 35% by 2035. Improving the thermal envelope of homes is one of the most impactful methods to improve building energy efficiency and DOE estimates a need to increase the current adoption rate of envelope retrofits by 25X by 2030. For this reason, The U.S. Department of Energy's Building Technologies Office is interested in funding projects that remove barriers to the deployment of residential retrofits at scale. In support of this mission, PNNL is collaborating with leading building science researchers and home performance entities to identify and characterize technical and economic barriers to façade retrofits to identify market-viable enclosure solutions and opportunities for an actionable plan to transform the market. The project identified re-siding projects as a prime opportunity for the addition of 1-inch or more of continuous exterior insulation combined with taping and detailing to create an air and water barrier. (Figure 1) This energy upgrade method has been named AIRS (Adding Insulation when

Re-Siding) and the research project targets up to 50 field demonstrations in at least three representative markets.

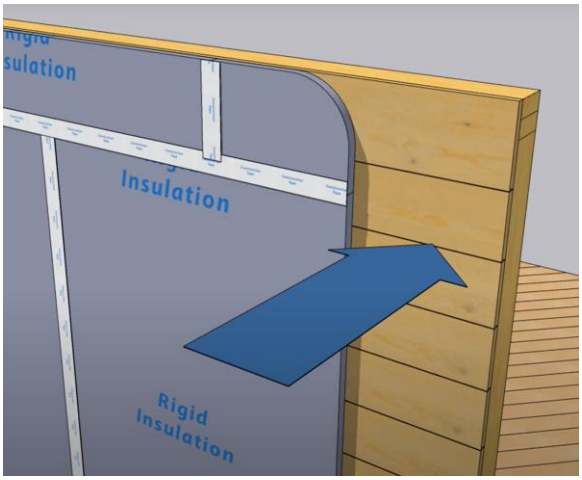


Figure 1. Rigid foam plastic insulation, taped and detailed as the air and water barrier.

The process of removing old siding and replacing with new is an ideal time to add exterior continuous insulation and air seal. One inch of rigid insulative sheathing, taped and detailed to act as the air and water barrier, typically improves thermal & moisture performance of walls, saves energy and utility cost, increases occupant comfort (temperature and noise), allows for the use of off-the-shelf trim and moldings, and maintains most siding warranties. Despite these many advantages, re-siding projects seldom include insulation.

PNNL is engaging re-siding contractors, local research partners, and non-profit organizations who serve low income and historically disadvantaged communities to perform AIRS energy upgrades and identify potential homes for enrollment. A primary project outcome is to gather professional feedback from re-siding contractors to produce educational and informational materials using real-world examples and to gather homeowner feedback and testimonials for use in a future campaign to make the case for this investment.

Background

The goal of AIRS 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 possible outcome given the limited scope. The most natural adopters would seem to be re-siders – their level of experience and training and the typical tools they are likely to have on hand is a realistic starting point, and by definition they are present during the re-siding effort that predicates the added insulation. Depending on quality, siding can last several decades (a typical warranty period is 15 years). Yet for 2021 the average length of time a U.S. homeowner lived in a house was about 8 years (Meyer, 2024), which implies that many homeowners have never dealt with the need to re-side their house and may be unfamiliar with their options – they may need a champion to pitch the possibility.

Re-Siding Motivation

A 2022 nationwide survey (Alside 2022) by Harris Poll® of 1,300 U.S. homeowners listed the most common reasons homeowners gave for updating their siding (respondents could choose multiple motivators):

- **39% - Damage:** Damage to siding – presumably through accident or a weather event – was the most common reason to replace siding; by comparison, of those who have not replaced siding, 41% said it's because their siding was in good condition.
- **36% - Aesthetics:** "they didn't like the way their old siding looked."
- **32% - Energy Efficiency:** hoped to boost their home's energy efficiency.
- **32% - Maintenance:** lower maintenance requirements was another desired outcome.

Siding alone has negligible thermal value and siding efforts typically do not include air sealing of any sort, so the 32% of homeowners who hope for improved energy efficiency are likely to be disappointed. But their aspirational goal seems hopeful for our education effort.

Insulation Motivation

For nearly a quarter of a century, Home Innovation Research Labs has conducted an annual Consumer Practices Survey (CPS). Ed Hudson, director of Market Research, reported several pertinent and persistent touchstones in the industry:

- Homeowners are **vastly more likely to add insulation to their walls at the time they first move in** than at any other time during their tenure
- **Insulated vinyl siding is a very small portion** of the total siding market
- **fan-fold backer is a very common inclusion**
- **Very few homeowners added 1-inch or more** of exterior continuous insulation during re-siding.
- Lower R-Value products tend to be easier to sell because they are less expensive.

To add to the potential for homeowner disappointment regarding aspirational energy improvements, nearly half of re-siding projects include fan-fold backer, which looks very much like insulation and often includes a radiant barrier scrim, but is too thin to achieve much thermal improvement, and is seldom well detailed for air sealing. The primary duty of fan-fold is to provide a uniform substrate for a smooth final wall plane that reduces callbacks about the new siding's appearance. Insulated vinyl siding has a non-uniform insulation layer due to the staggered cross-sectional profile and a thermal resistance range of just 2.0-3.5.

Energy Savings Motivation

The ResStock analysis tool was used to identify the wall insulation conditions for the full range of the existing housing stock in each state (Figure 2). For wood stud walls, the single most common condition for 31 of the 48 contiguous U.S. states is completely empty wall cavities – zero insulation in the stud bays. For another 13 states, well over half the walls have just R-7 or are uninsulated. Only four states in the upper Midwest are predominantly characterized by insulation levels of R-11 to R-19, with 16-in. o.c. 2x4 or 2x6 wood framing, respectively. Whole

building infiltration for existing U.S. housing stock was also characterized using the same resources (Figure 2). The predominant level of infiltration is a very leaky 15 ACH_{50}. Relatively tight construction characterized by 5 ACH_{50} or less – as required by the International Energy Efficiency Code (IECC) (ICC, 2021) for new construction in all climate zones – is enjoyed by a very small proportion of the existing housing stock.

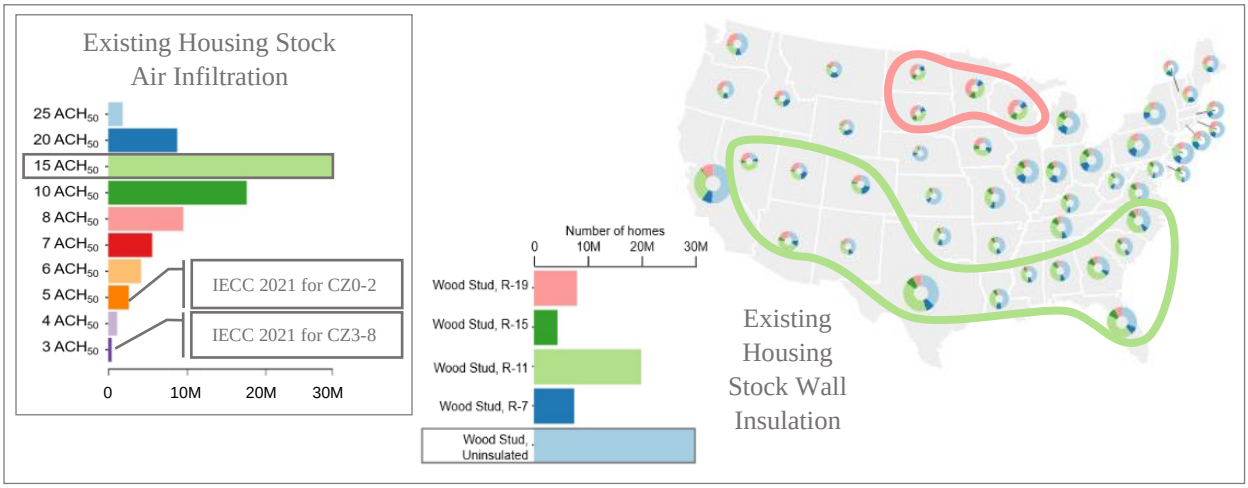


Figure 2. State-by-state proportional wall insulation and air infiltration for existing housing stock (wood framed) in the continental United States. *Source:* ResStock, NREL.

To test the nationwide energy savings potential and financial return of a variety of building envelope energy upgrades, including exterior continuous insulation and air sealing, the National Renewable Energy Laboratory (NREL) in collaboration with PNNL performed a robust techno-economic analysis using ResStock data, the BECP prototype building, and EnergyPlus (Present et al. 2024). The results indicated that adding R-6.5 (the approximate value of 1-in. of polyisocyanurate rigid foam board) taped and detailed as the air and water barrier was among the top energy performers. Overall, compared to other individual measures, adding a layer of exterior continuous insulation was the most effective single intervention for nationwide aggregated savings potential, saving nearly twice what each of the analyzed window solutions in isolation saved. Combining exterior insulation with a window energy upgrade saves approximately 20% more compared to exterior insulation alone.

Depending on the climate zone and existing conditions, simulated annual savings for site energy savings are up to 19% for 1-in. of added polyisocyanurate and up to 23% for 2-in. (Figure 3). Approximately 15% of this improvement was attributed to the reduction in whole building infiltration due to air sealing. Vintage ranges of pre-1950, 1950 to 1969, and 1970 to 1989 were used as a proxy to bin houses according to the relative energy efficiency associated with the existing conditions. To reduce analysis time, some climate zones were grouped. As expected, houses with the poorest existing conditions and in the coldest climates benefitted the most from the addition of R-6.5[1] exterior continuous insulation.

[1] The energy study did not take into consideration insulation R-value variation due to aging or temperature.

Building America Climate Zone	Vintage	Upgrade Run / Reference Run: 1″ insulation	2″ insulation	Storm windows	Triple pane windows	1″ insulation + storm windows	1″ insulation + triple pane windows	2″ insulation + storm windows	2″ insulation + triple pane windows
		Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing
Cold & Very Cold	Before 1950	19%	23%	8%	15%	21%	23%	26%	28%
	1950-1969	17%	21%	8%	13%	19%	20%	23%	24%
	1970-1989	10%	13%	8%	15%	11%	13%	14%	15%
Mixed-Humid	Before 1950	18%	22%	8%	14%	21%	23%	25%	27%
	1950-1969	17%	21%	7%	12%	19%	21%	23%	25%
	1970-1989	10%	12%	7%	13%	12%	15%	15%	17%
Marine	Before 1950	15%	20%	5%	9%	17%	19%	22%	24%
	1950-1969	14%	18%	4%	7%	16%	17%	20%	22%
	1970-1989	9%	12%	4%	8%	11%	12%	14%	15%
Hot-Dry & Mixed-Dry	Before 1950	12%	16%	4%	7%	14%	16%	18%	19%
	1950-1969	13%	17%	4%	7%	15%	17%	19%	21%
	1970-1989	8%	10%	4%	8%	11%	13%	13%	15%
Hot-Humid	Before 1950	13%	16%	6%	11%	16%	19%	19%	22%
	1950-1969	12%	15%	5%	10%	13%	16%	16%	19%
	1970-1989	7%	8%	6%	11%	9%	13%	10%	14%

Figure 3. Average (mean) of percent site energy savings for each upgrade scenario compared to the existing building stock (baseline reference scenario, aggregated by climate zone and vintage range. *Source:* Present et al. 2024

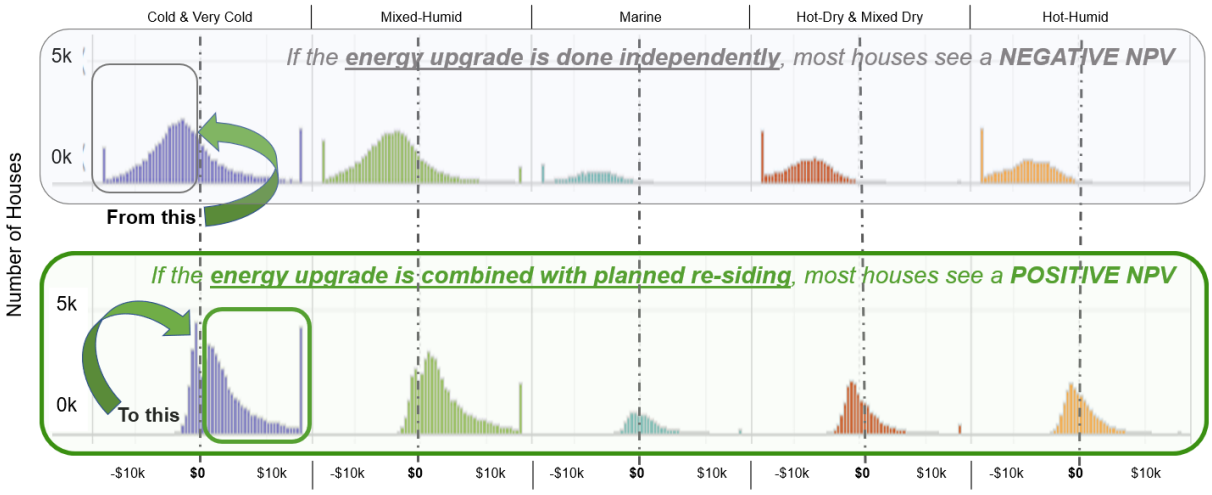


Figure 4. Distributions of NPV ($) for each retrofit case and reference scenario, separated by climate zone. The histograms use a bin size of $1,000, an overflow bin for $15,000 and higher, and an underflow bin for -$15,000 and lower; some climate zones were grouped. *Source:* Present et al. 2024.

Figure 4 shows that economic benefits were substantially greater for wall insulation upgrades added to an already planned and budgeted re-siding project (bottom row) as compared to undertaking the energy upgrade on its own (top row). Net Present Value flipped from predominantly negative when the insulation upgrade was done in isolation to strongly positive when it was combined with re-siding, i.e., the cost of the siding was already accounted for. In addition, average simple payback dropped to well under 10 years when the insulation was added at the time of an already planned and budgeted re-siding project. These calculations do not include the value of any rebates or incentives, either through the IRA, Weatherization Assistance Programs, local utility energy programs, or the IRA. For instance, the 25C income tax credit for insulation and air sealing would reduce first cost by $1200, substantially improving these already compelling NPVs.

Durability and Moisture Control

Proper design and installation are key components of AIRS. While AIRS is described generally as "1-in. or more" of rigid exterior insulation, specific guidance is provided (and will be expanded based on research results) to aid practitioners in choosing specific insulation types and thicknesses to ensure appropriate outcomes for the given climate zone, existing conditions, and chosen performance goals. Thermal, air, water, and water vapor control layers are all implicated in the addition of exterior insulation. Clear, reliable design and installation guidance is a primary work output of this research. While wall upgrades seldom trigger local inspections or performance requirements, the AIRS method includes a recommendation that homeowners and contractors design the upgraded wall configuration to meet or beat the International Energy Conservation Code (IECC, 2021) and the International Residential Code (IRC, 2021) if possible, with special attention to vapor retarder requirements in IRC Section 702.7 Vapor Retarders.

Implications for Cost, Skills, and Building Science Knowledge

Re-siding contractors' apparent inclination to avoid scope creep may limit their opportunities, but it also effectively protects them from pitfalls associated with venturing into new territory. The class action EIFS lawsuits in the mid-1990s (Architect, 2004) brought attention to unintended consequences of a seemingly simple and elegant wall solution that could inadvertently introduce moisture problems when the new, nearly impervious layers were improperly detailed or poorly installed. Similarly, early efforts to reduce air infiltration suffered a reputational hit when tightened buildings were not provided mechanical ventilation in adequate amounts to ensure healthy IAQ and control moisture (Green Building Advisor, 2008). Successful market adoption of the AIRS energy upgrade would avoid similar hiccups. In addition, observation of AIRS techniques utilized by both typical and high-performance builders will help identify cost-effective alternate approaches and region-specific opportunities or constraints.

Methods

With funding from the DOE, PNNL developed a plan to deploy a large sample of field demonstrations in the Building America Mixed-Humid region (Figure 5) to add real-world experience to the existing trove of simulations and market research. Mixed-Humid was chosen as the "sweet spot"—a location with both a large need and a large opportunity, and where 1-in. of rigid insulation was thermally appropriate but did not always invoke a need for jamb extensions

due to excessive thickening of walls. The project includes an advisory group (AG) with 14 stakeholders including contractors, manufacturers, trade organizations, municipal housing authorities, and product wholesalers. The preliminary field validation consisted of five proof-of-concept case studies. The field study targets 50 or more single family homes for the AIRS energy upgrade.

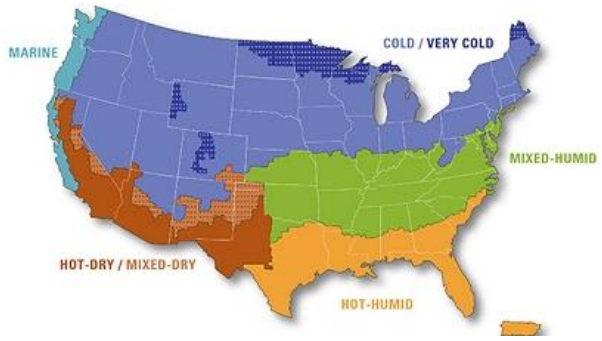


Figure 5. The Mixed-Humid climate region, as defined by Building America, was the initial target area for the AIRS field demonstrations. *Source:* https://basc.pnnl.gov/images/building-america-climate-zone-map

From a project perspective, the target professional participant is a contractor who regularly performs re-siding projects. The team did not require contractors to already provide insulation services to participate in AIRS. In addition to professional contractors, the project team engaged energy audit companies and community/housing organizations serving low-income households who performed residential retrofits in some capacity.

Per the project plan, participating re-siding contractors and applicable organizations would install one or more AIRS energy upgrades as an addition to an already planned and budgeted re-siding job. The roles of various partners are described below:

Contractors and Community/Housing Organizations:

- presents PNNL study information to homeowners who have requested re-siding bids or who are already under contract, or have enrolled in the organization's program
- modifies the scope-of-work for participating homeowners to add insulation and air sealing to the standard re-siding project,
- prepares crew for the added scope,
- works with PNNL and the advisory group to refine installation methods,
- sources, purchases, stores, and transports upgrade materials,
- installs the AIRS energy upgrade materials and requests installation guidance from PNNL research team as necessary,
- facilitates documentation of the installation process, including photos and videos,
- invoices PNNL for the additional cost of the energy upgrade for each house, up to $5,000 (based on the cost exercise from the initial five case studies),
- reports material and labor costs,
- reports unusual or challenging circumstances and novel solutions

Homeowner:

- signs informed consent,

- receives subsidized AIRS energy upgrade,
- installs free smart thermostats as provided (PNNL gathers interior conditions data and equipment runtime), and fixes issues when necessary,
- responds to before and after surveys or interviews,
- provides 12 months of utility bills both before and after the AIRS energy upgrade for a total of two years of utility records

Local Research Partner (auditor or energy consultant):

- facilitates communication and scheduling,
- facilitates communication with homeowner and contractor
- documents installation using photos, videos, notes, and conversation/interviews,
- conducts before and after blower door testing (with IR photography if conditions allow)

Results

With the earlier five case studies serving as the foundation for the AIRS field demonstration task, the project team initially developed a plan to engage re-siding contractors in the Mixed-Humid region who would, in turn, pitch AIRS to their existing customers who were considering or already under contract for a re-siding project. Contractors were identified for outreach through internet searches, word of mouth, and networking. When that failed to yield actionable leads, the team began to engage in less obvious search avenues, including local homeowners' associations, home builders' associations, building/trade organizations, and state licensing boards. This method resulted in a handful of new opportunities for engagement but was quickly exhausted with leads that eventually fizzled out.

During a brainstorming session, the idea of capitalizing on local energy consultants and their existing network became a possible path forward. The project team began by identifying large companies providing energy audits, construction inspections, or both for the state or local contractors or as members of the local utility's preferred providers for energy rebate and incentive programs. A Maryland company was the first to be identified and recruited, with the initial goal of having the company act as a third-party agent. Trustworthiness was a recurring topic when attempting to engage contractors, so the project team hoped that a local company with name recognition would be met with less suspicion. To narrow down the recruitment areas the project team decided to engage three to four similar companies across the mixed-humid climate zone who could all perform the same or similar functions. Additionally, these companies would act as a sort of "boots on the ground" and would act as "AIRS Subject Matter Experts (SMEs)" in addition to gathering the designated empirical and observational data. During this time, the project team also attempted to engage local utilities that offered weatherization programs. Unfortunately, stacking and braiding of funds for utilities operating weatherization programs was ultimately too complex to pursue.

Four third-party companies were identified and placed under contract, in Chesapeake Beach, MD, Nashville, TN, Knoxville, TN, and Asheville, NC. The SMEs were provided instruction and materials to recruit contractors and/or homeowners. They were also asked to spread the word about the AIRS project to any other local organizations who may be interested. Through one of the third-party contractors, the project team was introduced to Appalachia Service Project (ASP) a community organization serving low-income households in a four state region. ASP was eager for a new funding stream and was willing to engage program participants

with projects they felt fit the AIRS field demonstration research effort. Once introduced to the first community organization, the project team began engaging community organizations serving other areas in the mixed-humid climate zone, including Jerusalem Farm in Kansas City and River City Housing in Louisville, KY. This recruitment path was not one that had been considered prior, but the collaboration with organizations catering to low-income and under-served populations is helping to identify unique approaches and outcomes for this constituency.

Community non-profits that offer residential retrofits often focus on energy savings and comfort, rather than aesthetic upgrades like siding. Weatherization measures such as air sealing and attic insulation are common, as well as upgrades that address health and safety issues. Deep, frank conversation with these program leaders yielded an important finding: it's common for the non-profit and their services to first come to the attention of low-income homeowners when they are served with some sort of warning or fine by the city for a home safety or appearance violation. Non-profit groups must act quickly to help solve the problem or fines quickly accumulate. Ironically, if the homeowner had the excess resources to deal with the problem, it would never have manifested, but the fines are counterproductive and can result in a downward spiral. Many of these cases involve building components visible from the street: roofs, porches, windows, and siding, resulting in a good opportunity for AIRS energy upgrades. These non-profit organizations serve as a trusted source for information, have allowed homeowners to engage confidently with the project team and have revealed an important cohort and pathway to upgrades for the millions of homes that need energy and comfort improvements.

These research challenges have provided valuable insights. Re-siding contractors did not turn out to be the perfect "toe in the door" despite being in the right place at the right time. Formal interviews and casual conversation with owners, foremen, and installers in both large and small companies indicates that re-siders are even more conservative than the housing industry as a whole and are incentivized to stay in a narrow lane to reduce risk. This group tends to carefully limit their scope – working only on the exterior of the house and often focusing only on one or two types of claddings. Several interviewees shared stories they'd heard of moisture problems and indicated they perceived a potential expansion of liability. They also cited unfamiliar materials and tools, and lack of skill among their crew to tackle installation challenges that they associate with carpentry or other trades that are distinct from the means and methods associated with siding demolition, installation, and associated trim work.

Often their rationale was practical and direct. The backlog of work due to pandemic delays meant that siding contractors who used to focus on re-siding were in demand. Many found work in new construction where a backlog for production builders provided ample opportunity, and there was little incentive to expand their services. There is a strong case to be made that work for production builders avoids many of the negative aspects that plague one-off re-siding projects: selling, estimating, procurement, delivery, staging, dealing with callbacks, etc. Even without broadened opportunities into high-production new construction, contractors indicated that they were booked out months and could be very choosy with their schedule. They tended to favor projects that were narrowly tuned to their skillset, and felt the time, effort, cost, and uncertainty associated with adding a new service, albeit reasonably related, was not in their best interest.

The project team adjusted in early 2023 to focus more on messaging, marketing, and creative relationships, with an open mind to unusual opportunities. The middle and end of 2023 saw many positive changes in the economy and re-siding market that indicate competition is

increasing and re-siders have developed an appetite to learn new skills that distinguish them among their peers and allow them to respond to customer needs.

Engagement

Since the test plan modification, the AIRS Field Demo research team has:

- reviewed nearly 70 homeowners/houses for possible enrollment
- engaged more than 20 contractors in conversation about possible participation
- presented the project to over 300 interested parties via personal engagement or webinar
- presented at nearly a dozen conferences and expos
- sent recruitment postcards to
    - more than 8,000 homeowners in MD and NC
    - 86 contractors in Waldorf, MD and Asheville, NC
- modified the IRB[2] study plan to include interviews with homeowners or contractors who have previously installed siding or exterior continuous insulation or both
- Added two energy consulting organizations who will each act as fiduciaries to engage multiple re-siding contractors over the next 6 to 12 months
    - Earth Advantage in Portland OR will engage LatinoBuilt and other local trade organizations in an education-forward effort to disseminate the AIRS concept, train best practices and spread the concept to low income and under-served communities
    - Green Home Institute in Grand Rapids Michigan will focus on braiding funding from federal, state, and local programs to demonstrate the potential to bring the overall cost of these projects into reality and to educate local contractors on this critical consumer support aspect
- Added one market rate contractor – Quarve Contracting in Spring Lake Park, MN who will perform up to nine projects this summer to test the claim of synergistic opportunity and incremental cost premiums with the goal of identifying the value proposition.

Figure 6. Typical recruitment postcard for AIR

[2] The Institutional Review Board (IRB) oversees all research that includes human subjects to protect privacy and safety. The data gathered from homeowners includes personally identifiable information (PII) as well as indicators of lifestyle choices (utility and smart thermostat data).

Enrollment Status of AIRS Energy Upgrades:

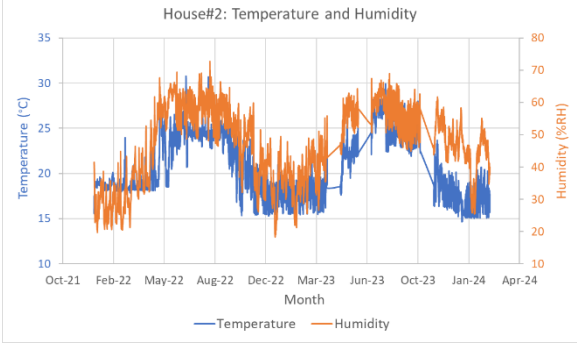
- 3 interview only participants
- 6 SF homes completed
- 24 low-income MF units completed – five 3-story buildings, Eastern Shore of MD
- 6 SF homes in process
- 2 homeowners denied because the liability associated with DIY cannot be supported
- 3 homeowners backed out for logistical reasons
- 3 homeowners could not find willing contractors
- ~20 projects under consideration

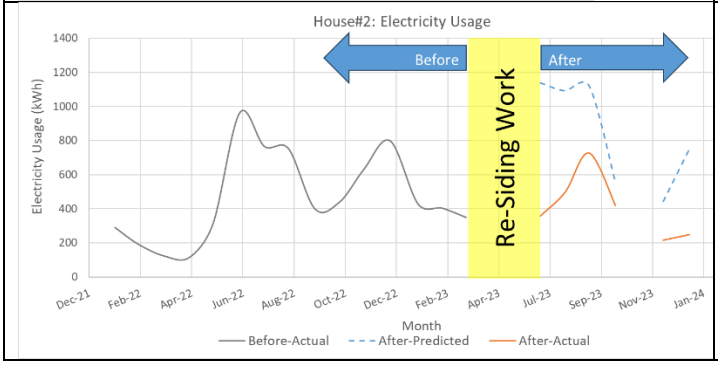
Data and Analysis

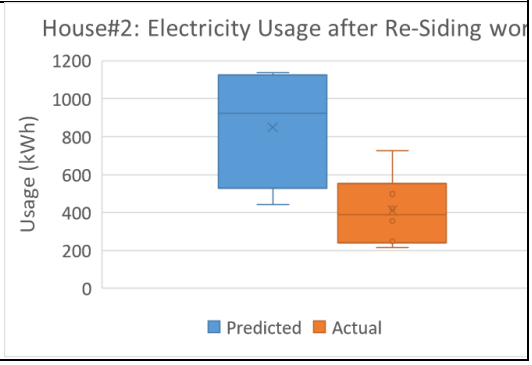
Preliminary data analytics were performed on the first two enrolled houses. The collected data includes thermostat set points, interior and exterior temperature and humidity, equipment run time, infiltration, and utility usage.

One full year of energy usage data from before the re-siding work was used to generate regression coefficients using each billing cycles number of days, heating degree days (HDD) and cooling degree days (CDD) using data from the BizEE Degree Days website (https://www.degreedays.net/), per the methodology presented in the energy calculation section. These regression coefficients were used to predict the usage data after the re-siding work. A Wilcoxon Signed Rank Test was conducted on the datasets between "Predicted" and "Actual" usages after the re-siding work. The Wilcoxon Signed Rank Test result shows that for the first two AIRS field demonstrations the actual energy usage is significantly lower than predicted; the confidence for ID001 is $p < 0.005$ and for ID002 is $p < 0.05$. The infiltration reduction for house #1 is nearly 35%; we do not yet have blower door results for house #2.

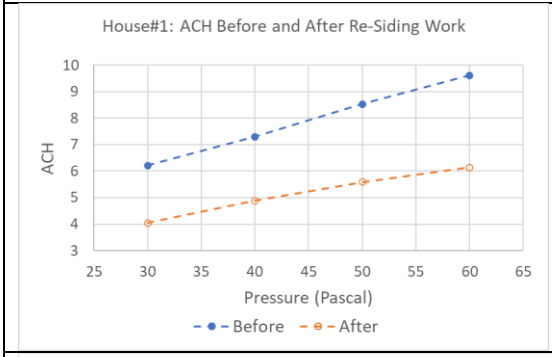
House #2 Kansas City, MO, weather station KMKC, 1 zone, installation 04/2023 – 06/2023.

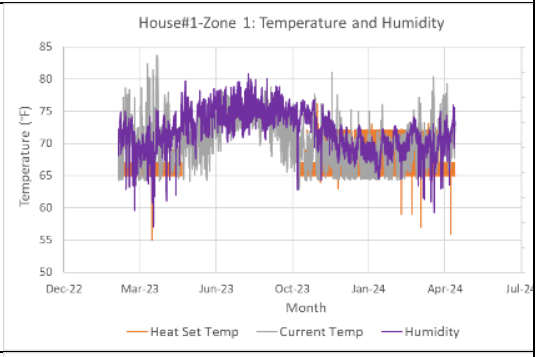


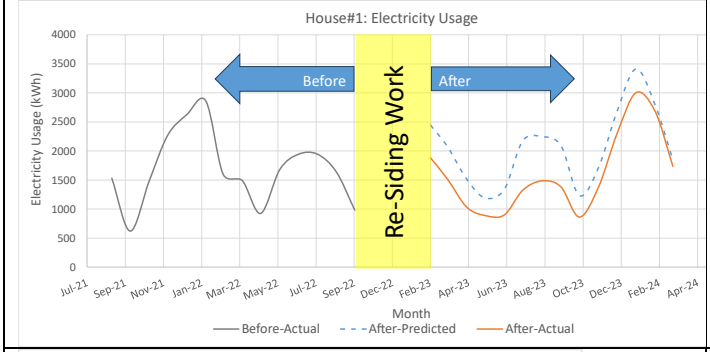


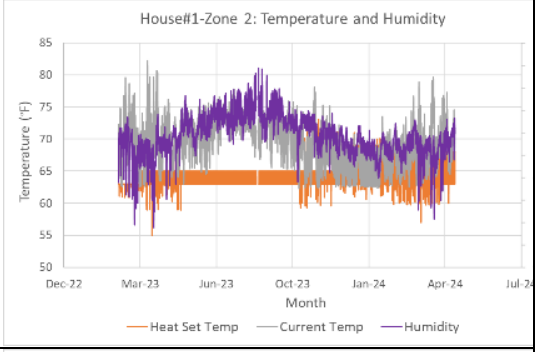


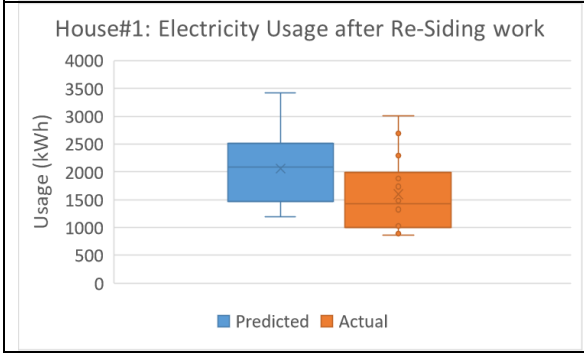
House #1: Chesnee, SC, weather station KSPA, 3 zones, installation: 12/2022 – 01/2023.

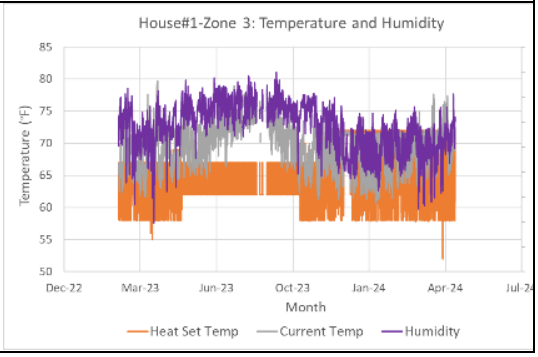












General Observations:

Anecdotal information has been gathered from both formal interviews and casual conversations with homeowners and contractors. While many of the following insights were either anticipated or brought to light during preliminary investigation, validation of these concerns and outcomes in actual practice carries weight with contractors and stakeholders who will be expected to make concrete changes, invest time and money, and risk their schedules and possibly reputations to adopt what is to them a novel practice.

- Lack of building science knowledge leads to mistakes that can put walls at risk of moisture damage
- Rumors of building science failures makes re-siders and contractors wary
- Re-siders may not understand:
    - The pros and cons of available insulation types
    - The need for taping all joints, penetrations, and transitions
    - The benefit of shingled layering of materials

    - The importance of clean butt joints
    - That most flashings and building tapes are pressure activated
    - The need for longer fasteners, different types of shafts and heads, cap nails, etc.
- Re-siders are not used to sourcing material and transporting FPIS
- Re-siders lack experience matching a particular FPIS with approved tapes and sealants
- Re-siders are more comfortable with building wrap than with FPIS (though their installation of both often did not meet best practices for air sealing)
- Re-siders may be unfamiliar with liquid-applied flashing, pan flashing and flexible flashing tapes, collars and boots, metal profiles to kick out or divert bulk water
- Some contractors limited the thickness of foam, reticent to tackle window trim
- Some crews did not follow guidance for flashing and counter-flashing windows
- Crew training is very informal and ad hoc in this sector (re-siding contractors)
- Re-siders are very familiar with and committed to standard vinyl siding trims and J-channel. They are unfamiliar with and not very receptive to other types of transition approaches and details whose purpose is water diversion (drip edges, drip caps, etc.)
- Flashing and counter flashing are not typical re-sider tasks
- Addition of FPIS seems to highlight existing damage and expose water-intrusion concerns more readily than simple re-siding.

Discussion

Installer Reactions

Sample (paraphrased) comments from interviews with various contractors indicate the need for practical training on building science principles, materials, and tools familiarity. But just as important are knowledge of potential energy and non-energy benefits and on-the-job support to overcome natural resistance. One manufacturer on the advisory group has noted several times that we must somehow identify the value proposition to overcome resistance, and that may necessarily come from customer demand, rather than an appeal to professional obligation in reference to energy or comfort, which are not typical considerations for re-siders.

- “Taping and detailing the foam is tedious = time-consuming = expensive”
- “I could only use my best crew for that job, and that crew didn’t want to do it again.”
- “No crew anywhere will do all the detailing this job demands unless someone stands over their shoulder the whole time.”
- “My customers can get just as much value out of a radiant barrier in the attic.”
- “Homeowners don’t want to pay for this extra work.”
- “Fan fold is almost as good.”
- “I’ll install whatever the customer asks for.”
- “We always prioritize quality for our customers, and AIRS adds to that quality.”
- “I like learning new techniques.”
- “I like being able to make the building better for the homeowner.”

Constructability Takeaways

The research team has drawn some initial conclusions that can aid us to focus our messaging and guide us in developing impactful installer/contractor support for design, marketing, and installation of AIRS:

- Focus on installation guidance (both general and region-specific) and provide simple combinations of compatible materials for desired outcomes to help in decision-making.
- Provide basic building science support to drive home the tried and true techniques to control bulk water and airflow by encouraging them to use their imaginations and common sense:
    - "Think about a drop of water – where will it go and how will it get out?"
    - Reduce gaps and fill holes – "tidy edges are easier to seal"
    - Adhesives are pressure activated – "Roll that tape!"
- Windows (even when not inset by thicker walls) are a known pain point: provide direct, clear, simple to enact solutions
- Develop guidance for assessing existing conditions and preparing for necessary repairs.
- Per discussions with contractors, preparation for AIRS this is not a typical pre-install effort for a standard re-siding job. Our guidance must recognize that:
    - It takes extra time; re-siding contractors make money based on high through-put.
    - They usually only address problems on the day and only to the extent necessary for basic performance
    - Vinyl siding (especially) is well-ventilated and therefore does not typically increase moisture durability issues, whereas poor installation of FPIS can create moisture problems. This could become an insurmountable burden without guidance and intervention.

Comfort Takeaways

So far, all homeowners agreed that after the AIRS energy upgrade their house was more comfortable and quieter. In addition,

- Several homeowners reported that they can now use rooms that previously were unlivable. For instance, in Kansas City the daughters' bedroom was often unacceptable cold, whereas a breakfast nook was usually too hot to spend time in. The homeowner declared that AIRS had restored many hundreds of square feet of living space to them.
- Some homeowners reported that the home's interior just felt "more solid" or "more private." The team has spent many meetings trying to quantify the value of such an outcome, or validate its effect – these can be compelling and important motivators.
- This exploratory research concluded that homeowners choosing additional wall insulation were primarily driven by comfort, while utility rebates and potential energy savings were secondary considerations, even though the AIRS energy upgrade was heavily subsidized by the research project.

No Cavity Insulation

Many non-profit organizations that repair or rehabilitate housing for disadvantaged clients have noted that it's typical for them to take on distressed buildings and find that the walls are entirely uninsulated. River City Housing in Louisville, KY estimated that up to 95% of their projects have empty stud cavities. Their typical approach is to blow in dense-pack cellulose. The research team was willing to enroll such houses but suggested the possibility of leaving the wall cavities alone and focusing all funds and energy on a more robust exterior layer of insulation. Several projects are planned to test this theory. River City currently pays between $1.40 and

$1.60/sf for dense pack. But this cost does not include drywall or paint repair since most projects will have this crew on site for other work. In other words, they are paying for the work, but it's not showing up in the dense-pack insulation line item. For comparison, BEopt's (outdated) estimate is $2.58/sf of wall for dense-pack retrofit. By contrast, the team estimates that 2-in. of foil-faced polyisocyanurate would be between $2 and $3/sf of wall, installed. This would not cover extra labor and material if jamb extensions are necessary for windows, however.

A $0.50/sf difference for a house with 1250 sf of wall would be about a $625 premium. Enumeration of potential advantages includes:

- Flood resilience – faster, cheaper cleanup because empty wall cavities allow for framing, sheathing and rigid insulation to simply be hosed off with a mild bleach water solution
- Freeze protection for pipes, more flexibility in coordination of trades (plumbing, wiring)
- Less occupant disruption (kids at home, etc.)
- No thermal bridges, continuous coverage at rim joist and belly band

A wall with thermal resistance concentrated at a single, exterior layer allows vapor from the inside to dry inward, and from the outside to dry outward, and keeps the temperature within the wall cavity above dewpoint to avoid condensation. Leaving wall cavities empty in favor of maximizing the exterior insulation offers additional, unique advantages for vulnerable communities, including 1) flood resilience – fast, cheap cleanup for speedy re-homing; 2) freeze protection for pipes; 3) flexibility in trades coordination; and 4) less disruption and more security for children home alone during the energy upgrade. River City's project superintendent calls this approach a potential game changer for project delivery and homeowner satisfaction for their constituency. Energy simulations show that 2-in. of exterior continuous insulation alone performs nearly the same as a hybrid solution of dense pack cellulose plus 1-in. of exterior continuous insulation, but the second approach is less durable, more complex, and more disruptive. Additional research is planned for more detailed cost estimation to allow reliable comparison.

Conclusion

Being immersed in the effort to inform contractors and homeowners about the opportunity to capture substantial improvements in comfort, noise, and energy just by "saying yes" to an opportunity that presents so infrequently and briefly (a planned and budgeted re-siding project) has provided insight, but also frustration. The team will continue to pursue all avenues to spread the word. Results so far are anecdotal and limited. As more homes are enrolled the cost, utility, infiltration, and construction data will allow the team to develop identification of – and solutions for – the known technical challenges. The production and dissemination of well-supported installation guidance and compelling messaging are key goals.

Thermal comfort and noise improvements are clearly reliable outcomes at a level that homeowners notice and are impressed by. As with EPA's Energy Star program, we will continue to focus on these as intrinsic goals worth pursuing, at least as important as utility bill savings. The Energy Star "Expert Home Improvements" program lists Comfort, Savings, Quality and Value, and A Cleaner Environment, in that order. Anecdotal evidence from the AIRS Field Demonstration research indicates this message resonates with homeowners and remodeling contractors, though so far re-siding contractors are less attuned. It's our job to identify the receptive paths and provide useful, actionable guidance.

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